EFFECTS OF SPEED ZONING IN SUBURBAN AREAS

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Joint Highway Research Project

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by

C. M. ELMBERG

Final Report

EFFECT OF SPEED ZONING IN SUBURBAN AREAS

TO: K. B. Woods, Director
Joint Highway Research Project

June 8, 1960

FROM: H. L. Michael, Assistant Director
Joint Highway Research Project

File: 8-4-19

Attached is a final report entitled, "Effect of Speed Zoning in Suburban Areas", by Curt M. Elmberg. The research was conducted under the supervision of Professor H. L. Michael of our staff. Mr. Elmberg also used the research for his thesis for the MSCE degree from Purdue University.

The research reports that land development along a roadway does have an effect on the speed of travel but the effect was so variable that a quantitative evaluation of such effect was not possible for the various types and degrees of land development. The study also indicated that drivers on the average do not determine their speed of travel from speed limit signs but rather from their appraisal of the location and a safe speed.

The report is presented to the Board for the record.

Respectfully submitted,

Harold L Michael
Harold L. Michael, Secretary

HLM:kmc

Attachment

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EFFECT OF SPEED ZONING IN SUBURBAN AREAS

by

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Graduate Assistant

Joint Highway Research Project
File: 8-4-19
Project: C-36-17S

Purdue University
Lafayette, Indiana

June 8, 1960

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ABSTRACT

Elmberg, Curt Martin. MSCE, Purdue University, June 1960. EFFECTS OF SPEED ZONING IN SUBURBAN AREAS. Major Professor: Harold L. Michael.

Speed control has been identified as one of the most important tools in attempting to counteract excessively fast driving and to reduce accidents. At the same time, speed control also has been recognized as a difficult and controversial issue due to the fact that criteria for establishing speed zones do not have the same degree of acceptability as have other traffic controls, for example no-passing zones or traffic signals. Numerous speed studies have been conducted throughout the United States; very few, however, deal with speed patterns within the fringe area between the genuine rural and genuine urban area, generally termed the suburban area.

This thesis reports the results of a study at five suburban areas of the combined effect of various speed limits and roadside development on driver speed patterns. Three of the locations concerned were two-lane U.S. highways traversing suburban development of predominantly residential, commercial, and industrial type, respectively. One of the locations was a four-lane, partially divided, highway which recently had been reconstructed from two lanes to four lanes. No speed limits had been posted along this highway after the reconstruction

had been completed. Consequently, this highway was an excellent location for studying the effects of various posted speed limits, making possible comparisons between unrestricted and restricted speeds. Only free-moving passenger vehicles traveling on dry pavement under optimum day and night visibility conditions were considered. Speed patterns for local and non-local vehicles were analyzed separately; local vehicles being those officially registered in the actual county as verified by the prefix on the license plate. Spot speeds were recorded, using an Electro-matic radar speed meter, at various points at each location, during day and night, before and after speed limit signs had been posted. Altogether, 31,573 vehicles were recorded, of which 20,552 were during the day and 11,021 were during the night.

The study revealed that the drivers paid little, if any, attention to posted speed limits. They seemed to choose a speed which they themselves considered appropriate for prevailing conditions. Non-local vehicles traveled significantly faster than local vehicles in many instances. Noticeable differences between day speeds and night speeds were also recorded at some sites. Variabilities in the speed distribution at a few individual stations for the same sign and road conditions were unexpectedly high, thus somewhat challenging the accuracy of fixed-point speed measurements.

The influence on the speed pattern of various types of roadside development was difficult to distinguish intelligibly, and was evidenced by the revelation of distinct interaction effects between the diverse factors. The limited number of locations, adequate for the roadside development study, also contributed to making difficult an ultimate conclusion.

INTRODUCTION

Speed

For years philosophers have argued that speed, per se, is not destructive. The elliptical path traveled by the earth with a speed exceeding 66,000 miles per hour in its annual trip around the sun is actually a highly advanced freeway. There are, however, no conflicts or frictions along this freeway in terms of crossroads and other vehicles.

To a mathematician, physicist, or astronomer speed may simply mean the ratio of distance to time; to a traffic engineer speed, per se, means nothing, but in conjunction with terms such as mean speed, speed percentiles, speed zones, and others it has a significant connotation.

Man always has strived and always will strive for attaining faster and faster speeds on the land, on the sea, and in the air. The problem today is not primarily to develop vehicles which are able to travel with high speeds but merely to develop additional devices for man which will assist him in controlling and utilizing the speeds attained safely and efficiently. Automotive vehicles have improved tremendously during the last half century. The record for the fastest mile in 1898 was 39 miles per hour and in 1950 394 miles per hour (55)*. The average driver, however, has shown very little ability to cope

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* Numbers in parentheses refer to listings in the bibliography.

safely with high speeds. There may be safe highways and safe vehicles but no safe drivers, hence regulations and restrictions. McMonagle (44) voices this in the following quotation: "Speed is one of the great essential benefits which make highway transportation indispensable in modern America. It must be provided for and protected."

Speed and Safety

What speed is safe? Drastically expressed, the only safe speed is zero mile per hour (29, 66). Accidents occur at all speeds. However, higher speeds increase the chances of exposure to situations, the rapidity at which these develop reduces the ability of the driver to react properly and may lead to an accident. It is generally true that the speed determines the severity of an accident (17).

With the early growth of the use of motor vehicles special attention was given the problem of safe speed. In 1925 Dickinson and Marvin (4) defined safe speed as "such that a driver will be able to stop his vehicle within the distance ahead that is certain to be free from any obstruction". This is certainly true today, too. What is then a good driver? Is he the one who always drives at a safe speed? Johnston (34) defines him as "one who starting on a journey regardless of the roadway, weather, vehicle, or traffic arrives at his destination without having any trouble himself or without causing anyone else any trouble". A Yale University study of driver behavior (34) disclosed that 81 per cent of the drivers do not get involved in serious traffic accidents at all; that 15 per cent have only one accident each; and that the remaining 4 per cent account for 36 per cent of all accidents.

Another study (41) revealed that the individual speeds of the drivers with accident records are slightly higher than those for the drivers without accident records.

Yet, speed is often advocated being the greatest contributing cause to accidents. Thorough studies, however, have indicated that this may not be entirely true. A study in Minnesota of 40,000 accidents (29) in which data as to vehicle speeds were clearly stated showed that if every accident in which speed was the only violation could have been prevented the number of accidents would have been reduced less than 10 per cent. Also, if all accidents could have been prevented in which speed was the primary cause of the accident the savings in number of accidents would not have been much greater. Actually, nearly 75 per cent of the accidents involved some other violation but no speed violation. In 1955 the Chicago Park District ascribed speed as the principal cause of only 9 per cent of the automobile accidents (42). As stated previously, speed does determine the severity of an accident but is not necessarily the causative factor. "Speed is only dangerous relative to attendant conditions" (44).

Speed Control

Speed control is probably one of the most important, difficult, and controversial problems of traffic operations. Criteria for establishing speed zones do not have the degree of acceptability as have such other traffic controls as no passing zones or traffic signals. Speed control is important because it facilitates movement at uniform speed which is desirable from the standpoint of capacity and safety;

speed control is difficult because variations in driving behavior between individuals do complicate the establishment of adequate, reasonable, and, as far as possible, uniform warrants based on objective speed surveys; speed control is controversial because of divergences of opinion among engineers, enforcement officers, the motorists, and the people living along the highway as to appropriate methods for controlling speeds.

Speed control is not an invention of recent date; sections of the Roman Law cover the proper operation of chariots. Newport, Rhode Island, set up the first known speed control legislation in the United States in 1678, when a law was passed forbidding reckless and fast driving of horsedrawn vehicles. In 1757 the City of Boston limited riding on horses and driving of horsedrawn vehicles to walking speed (50). With the entrance of the automobile speed legislation became crucial. A gentleman, named T. H. Shevlin, was fined ten dollars for speeding in excess of 10 miles per hour in Minneapolis in 1902 (36). Though the speed laws passed generally decreed "speed should be reasonable and prudent for the conditions prevalent" they left the determination of such speeds to enforcing officers. In the late 1920's three kinds of speed limits had crystallized: the 'no speed limit', i.e., speed should be reasonable and prudent, the 'prima facie speed limit', and the 'absolute speed limit'. During the 1930's arguments concerning advantages and disadvantages of the respective speed limits filled magazines and newspapers throughout the nation (5, 8, 9, 10). Accordingly, speed laws were changed in various states; one system was abolished, another adopted. The general trend was towards absolute

speed limits, particularly within the cities, because such limits were generally easier to enforce (3, 55).

There is no doubt that speed control is desirable, because it assists the motorist in selecting speeds that are safe and that permit him to obtain the maximum utility, economy, and convenience from his vehicle and the road (47). Speed zoning is defined as the establishment of safe and reasonable speed limits, based upon traffic and engineering study, for certain special zones or sections of street or highway where the general state-wide legislative speed limits do not fit the road and traffic conditions (47). To be enforced speed limits must be reasonable; establishing low limits and allowing a high tolerance must be characterized as an unsound policy. Furthermore, speed limits should be established for favorable weather and traffic conditions; further reduction due to inclement conditions should still be regarded as the responsibility of the driver.

Approaching an urban area, speed zones generally begin in the fringe area, usually termed the suburban, in which auxiliary roadside development of all kinds may be expected, such as filling stations, drive-in-theaters, cafes, trailer courts, et cetera. This transition zone between rural and urban development should also be a transition zone for speed limits. Type of roadside development may or may not influence the speed pattern in this area. A reasonable signing of speed limits should reflect the gradual and natural reduction of the speed within the suburban area; accordingly, a series of speed limit signs, properly posted, gradually limiting the speed from the state-wide limit in the rural area to the limit generally used in the urban area may

constitute the best warrant available. An abrupt change in the speed limit from the high rural limit to the low urban limit within the suburban area, oftentimes at the border of the urban area regardless of development, is, however, commonplace. Very few drivers like to apply the brakes without any conceivable reason, and, therefore, the low speed limit often is entirely or partly disregarded until roadside development and inclosing traffic automatically regulate the speed.

Speed and Enforcement

A speed limit has to be reasonable in order to be enforced. An unreasonably low speed limit will generally be disobeyed, and arresting everybody violating such a limit requires a police force of dimensions inconceivable. A posted speed limit must be self enforcing. A speed limit is ordinarily not considered self enforcing if more than five per cent of the drivers exceed the limit by 5 miles per hour or more (34). Most enforcement agencies also agree that in areas where speed is a problem, apprehension of even one per cent of the drivers would be difficult.

Theoretically, if a posted speed limit is determined by an objective study enforcement should take place even though the limit is exceeded by only one mile per hour. Because of deficiencies of the equipment used in checking speeds (75) and the speedometers of the vehicles, a tolerance is customarily maintained, though not publicly known, before apprehension takes place. The most commonly used tolerance is five miles per hour (59). Notwithstanding that speedometer error is the primary reason for allowing tolerances, several other

reasons, more or less important, exist according to a study by the Eno Foundation (59). Table 1 shows some of the most characteristic reasons, discovered by this study, for allowing tolerances in enforcement of speed regulations by state as well as city enforcing agencies.

TABLE 1*

REASONS WHY TOLERANCES ARE ALLOWED IN ENFORCEMENT OF SPEED REGULATIONS

Reason	Per Cent of Reasons Reported				
	State	Cities with Population			
		10,000 - 25,000	25,000 - 50,000	50,000 - 100,000	Over 100,000
Adjustment for Speedometer Errors	56	40	36	35	41
Create Public Good Will	25	36	39	27	39
Courts Require for Conviction	16	14	17	19	13
Numerical Limits Considered Too Low	3	10	8	19	7
Total	100	100	100	100	100

* Source: Reference (59).

Purpose

The purpose of this investigation was to study the effect of speed zoning in a suburban area not previously zoned. The general effect of speed limit signs on the speed pattern, as well as some specific effects related to the posting of signs and the influence of roadside development were to be analyzed. It was also hoped that information pertaining to the establishment of adequate warrants for speed zoning in suburban areas would be obtained through this study.

PREVIOUS INVESTIGATIONS

Continuous records of speed trends before World War II are very scarce. Some states made speed surveys of fairly intensive character during the depression years of the 1930's but these studies were not repeated in a way which would have permitted year-to-year comparisons. With the restrictions on gasoline and rubber followed by a nation-wide speed limit of 35 miles per hour in 1942, the states began to make continuing large scale speed studies.

The earliest major speed-trend information came from Rhode Island, where the average speed showed a steady increase from 22 miles per hour in 1925 to 34 miles per hour in 1934 (55). Another prewar study at seven locations in New York in 1935 disclosed an average speed of 43.5 miles per hour. In 1950 the same locations were re-studied, and the average speed was then 41.7 miles per hour, accompanied by a noticeable increase in the concentration of speeds around their central values (55).

During the 1950's extensive speed studies were conducted throughout the United States. Speed has been correlated with factors pertaining to the drivers, such as sex, age, occupation; to the vehicles such as type, age, mileage; to the roads, such as alignment, width and number of lanes, type and width of medians and shoulders, among many other things. The bibliography covers this material fairly well.

Studying speed reports from various states, one notes that almost

every study was concerned with the number of drivers exceeding the posted speed limits. McClintock states already in 1931 (8): "It is generally known among competent observers that speed limits have negligible effect upon the speed at which vehicles are operated. Drivers operate at that speed which appears to them to be safe and desirable under the circumstances. Studies made in states having fixed limits, prima facie limits and no limits resulted in approximately the same average speed under comparable traffic conditions." In 1931 speed tests in Maryland and in New Jersey, where a prima facie law for 40 miles per hour was in effect, and in Massachusetts, where a 20 mile per hour prima facie law was in effect revealed that the speed chosen by the majority of drivers was substantially the same, about 35 miles per hour (10). Nearly 25 years later the problem was still the same; in a ten state survey in the eastern part of the United States 99 per cent of all drivers ignored speed limits of 15 to 25 miles per hour (62). Table 2 shows results from a speed test on a four lane divided highway (U.S. 40) in Maryland (13), in which the additional effect of a 'speed zone ahead' sign was analyzed.

Conradt (25) frankly proclaims: "Motorists generally ignore posted speed limits in New Mexico. Two likely reasons for this regard are the setting of speed limits too low and the irregular, haphazard signing of speed zones. In some communities more than 90 per cent of the drivers exceeded the posted limit; enforcement impractical, not to say impossible." Results from the tests in New Mexico (25), which included raising as well as lowering speed limits, are shown in Table 3. This study indubitably reveals that raising a speed limit close to the true 85th percentile speed does not imply that the speed will increase

TABLE 2*

EFFECTS OF SPEED ZONING IN MARYLAND

	Signs Posted		No Signs Posted
	30 MPH	Speed Zone Ahead 30 MPH	55 MPH
Average Speed (mph)	43.4	43.6	45.5
Per cent of Vehicles			
- under 34 mph (%)	5.1	5.7	3.3
- between 35 - 59 mph (%)	94.6	93.7	96.0
- over 60 mph (%)	0.3	0.6	0.7

* Source: Reference (13).

significantly after the alteration; in fact, a slight decrease is discernible in this case.

A recent study in Illinois (39), including raising and lowering of existing speed limits and establishing of limits where none previously existed, indicated that the physical increasing of the numbers on speed limit signs did not of itself generate higher speed; nor did the physical changing alter the normal speed pattern within a zone. Furthermore, no evidence existed to indicate that accidents increased when speed limits were raised, nor materially reduced when limits were lowered or established.

It is frequently claimed that lowering speed limits reduces accidents; however, a reduction of accidents at many such sites does not necessarily indicate a greater obedience of the posted limits.

TABLE 3*

EFFECTS OF SPEED ZONING IN NEW MEXICO

Community	Year	Speed Limit mph	85th Percentile Speed mph
Bernalillo	1951	20	33.5
	1953	30	31
Mesquite	1952	60	52
	1953	45	49.5
Vado	1952	60	45.5
	1953	45	45.5
Berino	1952	25	47.5
	1953	45	47

* Source: Reference (25).

Other factors such as increased enforcement activity, newspaper editorials, and safety slogans in conjunction with the alteration of a speed limit undoubtedly contribute to making the drivers more alert. A driver who knowingly violates the speed limit may also be more alert. A study in Kansas (67) verified that a reduction of accidents took place when a 35 mile per hour speed zone was installed in an area previously not zoned; yet, 70 per cent of the drivers exceeded the limit. On a four lane highway, zoned for 55 miles per hour, the number of accidents decreased after the zoning; yet, two thirds of the drivers

violated the limit. In this case it is very hazardous to conclude that the posted speed limits solely accounted for the reduction of the accidents.

A very interesting experiment regarding speed zoning was performed in 1956 in the city of Nashville, Tennessee (30). It had become apparent that the universal 30 mile per hour speed limit was too slow for some sections of the city. It was then voiced that setting the speed limits at some odd numeral such as 34 or 39 miles per hour would probably attract attention and improve the observance of the posted limits. Except for noticeable publicity when first erected by the time the speed observations were made it became evident that the effect of these signs was insignificant when compared with conventional signs indicating 35 and 40 miles per hour, respectively.

To measure deviations between posted limits and driving speeds a survey was conducted several years ago over a 500-mile section of a principal north-south U.S. route through three southeastern states (60). Although limitation were imposed, primarily by obtaining speed data using the 'floating car method' and using only a single test run, particular care was taken to attain "average conditions". Of noteworthy interest was the separation of speed data by physical conditions such as type of road and type of area; 86 per cent of the 500-mile section was rural, 7 per cent suburban, and 7 per cent urban. Table 4 shows distances posted by various speed limits, Table 5 the driving speeds related to those limits. In suburban districts the principal differences occurred where the posted speeds were 35 miles per hour or less. Where higher speed limits were indicated for suburban areas, the travel

TABLE 4*

DISTANCES POSTED BY VARIOUS SPEED LIMITS

Posted Speed Limit (m.p.h.)	Per Cent of Total Mileage (500 miles)			
	Rural Areas	Suburban Areas	Urban Areas	All Areas
15 and 20	0.1	0.6	1.0	1.7
25	10.4	3.0	2.9	16.3
30	5.2	1.0	2.4	8.6
35	3.8	1.8	0.7	6.3
40	1.0	0.6	---	1.6
45	---	---	---	---
50	53.7	---	---	53.7
55	11.8	---	---	11.8
Totals	86.0	7.0	7.0	100.0

* Source: Reference (60).

speeds were more often actually lower than the posted speed. Sixty-one per cent of the drivers violated the speed limits in the suburban areas compared to 43 per cent in the urban and 52 per cent in the rural districts.

This study distinctly reveals that the suburban area is more critical as to proper and reasonable zoning than any one of the other areas. Consequently, adequate and credible zoning of this transition area will definitely promote improved compliance even in the urban area. Although numerous speed surveys have been conducted throughout the United States,

TABLE 5[†]

DRIVING SPEEDS RELATED TO POSTED SPEED LIMITS

Posted Speed Limit (m.p.h.)	Average Driving Speed (mph)			Per Cent by Which Limits Exceeded		
	Rural Areas	Suburban Areas	Urban Areas	Rural Areas	Suburban Areas	Urban Areas
15	42	30	23	250	100	55
25	51	42	35	104	66	41
30	50	44	41	66	47	36
35	53	47	44	51	35	26
40	50	45	*	25	13	*
50	58	34	*	16	-35	*
55	60	*	*	9	*	*

* No mileage posted at these limits.

† Source: Reference (60).

very few reported concerned only the suburban area, as explicitly separated from the urban area. However, this is due to the fact that a definite borderline between the two areas is difficult, or impossible, to define in many cases. With growing urban areas the suburban area is constantly moving. A district which was defined suburban at one time might be termed urban within a few years. Alteration of established speed limits might therefore be warranted. Extending the speed limit established in the urban district to incorporate the suburban district merely from a standpoint of convenience is hardly a sound policy; nor is it sound to allow suburban development to flourish without pertinent

consideration of adequate speed control.

More research on the influence of suburbanization on traveled speeds is needed in order to ascertain warrants for establishing reasonable and enforceable speed zones. The state-wide speed limits on the open highways in the rural areas are generally reasonable. In suburban and urban areas speed limits are, in too many cases, too low and are not posted according to actual conditions, hence making a customarily law-abiding citizen a violator without any greater sense of guilt or wrongdoing.

SCOPE

Limits of Study

Some difficulty was involved in choosing the locations outside the Lafayette area at which studies were to be performed. Study sites had to be within a reasonable distance of Lafayette, carry sufficient traffic so as to expedite the collection of data and be of such a nature that comparisons of obtained data between the locations primarily reflected the influence, if any, of roadside development of various types, rather than differences due to other factors such as posted speed limits, alignment, signals, etc. Therefore, the following requirements were used for selection of a highway approaching an urban area and along which a series of speed studies were performed within the suburban region:

1. The highway had to be as straight and level as possible so as to facilitate the visual perception of the suburban as well as the urban area.
2. The posted speed limits had to be reasonable, and the limits preferably spaced in gradually decreasing order.
3. No signals, stop signs or other signs which might have an adverse effect upon the speed pattern should be present.
4. The roadside development should be predominantly of one type or another; residential, commercial, or industrial.

Considerable reconnaissance was done to find adequate locations

fulfilling the above requirements and only a few could actually be found within a reasonable distance of Lafayette.

The types of vehicles under consideration were passenger cars only because speed zoning is primarily based upon speed data obtained for these vehicles. Furthermore, since the major part of this study was concerned with changing speed limits and the study of the effects of these alterations, some thought had to be given to the residence of the vehicles. Classification was thus done into local vehicles and non-local vehicles, the former generally defined as vehicles registered in Indiana and carrying the prefix letters assigned to the county in which the study was performed. Table 6 shows the definitions used to classify the various vehicles. A separation of state-owned cars into one local and one non-local group was considered necessary because of the great number of trips by state-owned Purdue vehicles, which thus were classified as local in Tippecanoe county, where the major part of the study was carried out. Although some question could be raised about the accuracy of the classification of vehicles of type 3 in Table 6 the number of vehicles in that group is substantially smaller compared to that in other groups, hence causing little or no influence on the final result. A more intricate problem was the classification of non-local vehicles owned and operated by Purdue students. Basically, these vehicles should be classified as local in Tippecanoe county but to separate "true" non-local vehicles from such "false" ones was too difficult a task to perform. Moreover, since the study was planned to be carried out mainly during the summer months the actual number of Purdue students was reduced considerably. The reason for this concern about local and non-local vehicle classification in Tippecanoe county was the effect several

TABLE 6

CLASSIFICATION OF VEHICLES

Local Vehicles	Non-local Vehicles
1. Indiana vehicles carrying prefix letters assigned the actual county.	1. Indiana vehicles carrying prefix letters not assigned the actual county.
2. Indiana state owned vehicles which residence was known to be the actual county.	2. Indiana state owned vehicles which could not be traced as resident in the actual county.
3. Indiana vehicles carrying dealer plates.	3. Indiana vehicles carrying amateur radio plates, veteran disability plates, and similar special plates.
	4. Out of state vehicles.

alterations of sign conditions might have on drivers who were familiar to the environment. A familiar driver may notice a sudden change of a previously existing speed limit and be alert whereas an unfamiliar driver perceives the posted speed limit like any other speed limit, obeying or disobeying it.

A study of the effect of speed zoning in general cannot be regarded comprehensive unless speed zoning and visibility are related. Therefore, at all locations speed studies were also performed during night hours. It was believed that a similar classification of the vehicles during the night as was done during the day should be possible but several preliminary surveys disclosed it to be so difficult that the accuracy of the night studies might be disputed. These surveys thus

indicated that, on the average, every three vehicles had either no light illuminating the license plate or the light was in such a bad condition that it was impossible to read the license plate, particularly when the speed was high. Accordingly, no classification was done during night hours.

Only free-moving through vehicles were recorded, a free-moving vehicle having been defined for the purpose of this study as one whose speed was not affected by the immediate presence of other vehicles in its path. In accordance with this definition only the lead vehicle in a platoon was recorded. The minimum allowable headway for recording was about five seconds on a two lane highway (49) but slightly less on a four lane highway, where it oftentimes had to be judged by the recorder from case to case whether or not a passing vehicle was free-moving. Passing vehicles on a two lane highway and vehicles turning off the highway after passing the speed recording station within a distance of that station which was deemed to have affected the speed were not recorded. Moreover, since the studies were performed in the near vicinity of urban areas quite a few police cars were patroling the highways. Neither those cars nor any vehicles in the front of or in the rear of them were recorded (18). However, in a sense all vehicles were actually recorded since the volume of vehicles passing the speed measurement station was of particular interest, this volume thus consisting of vehicles whose speed was recorded and vehicles whose speed was not recorded due to the factors mentioned above.

In order to reduce the number of variables data were collected on weekdays only and, as far as possible, at the same times each day.

No night studies were carried out on Fridays because the characteristics of travel those nights was significantly different from other weekdays, particularly during the summer months (46).

Data collection took place only when the pavement was dry and optimum atmospheric conditions, absence of fog or haze, were present. A preliminary study was performed dealing with the effects upon the speed on dry and wet pavement to test whether a light rainfall during a speed survey would affect the results significantly. The study disclosed that a light rainfall did not affect the speed significantly in daylight; a light rainfall was defined as one which wetted the surface gradually but not so heavy that the windshieldwipers had to operate. Even a light rainfall at night caused reductions in speed mainly due to glare from reflected light on the wet pavement. This has also been found in investigations by other authors (57, 61). Hence, the actual study was not intended to investigate this matter in detail; merely to obtain some information in order to justify whether or not an already initiated survey should endure in case of rain.

The study was principally associated with the inbound flow of traffic towards the urban area although the outbound flow was partially studied in one suburban area. With very few exceptions, at the same speed measurement station, day and night studies took place the very same day. In some cases, efforts were also made to check the speeds continuously at some stations on the same weekday. However, great success was not accomplished because of the large number of stations covered.

Reconnaissance studies and preliminary surveys for determining

sample size were conducted in December 1958 and the first months of 1959. The actual collection of speed data took place from March through November 1959 with uninterrupted weekly surveys from May through September. Altogether, about 31,500 passenger vehicles were checked in this study.

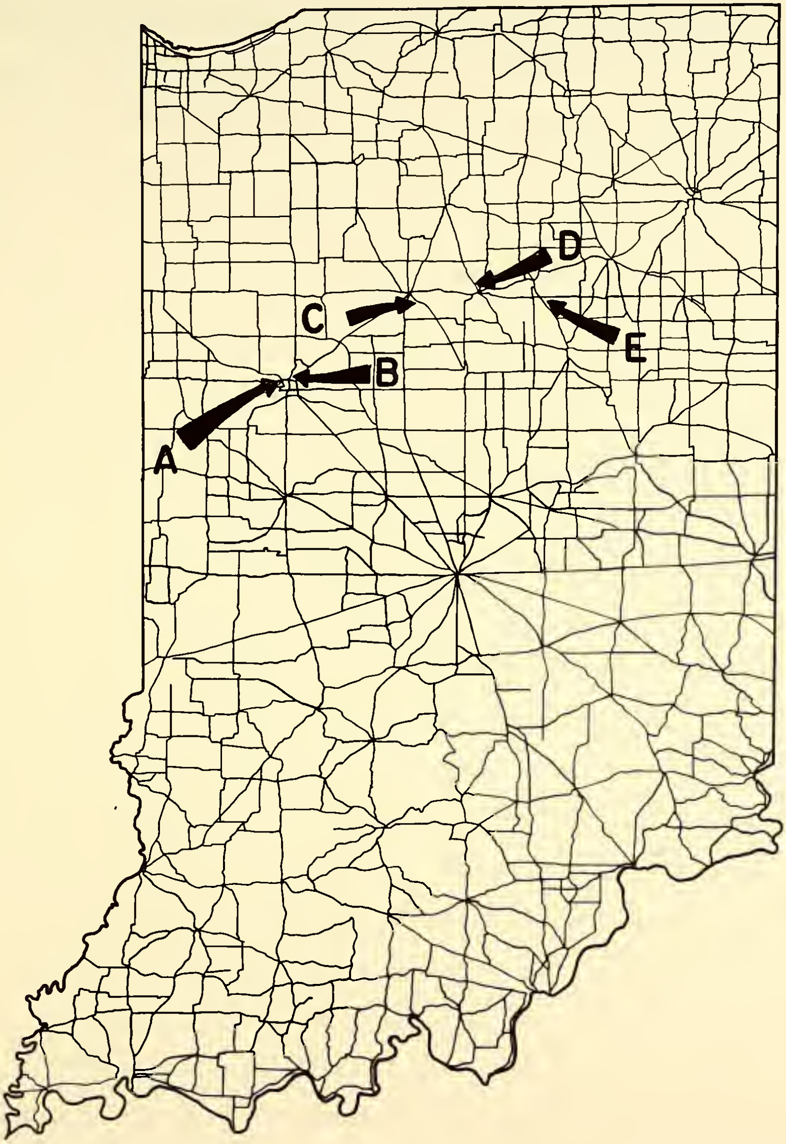
Locations

The warrants for selecting study locations, previously mentioned on page 17, limited the number of usable sites although several urban areas were visited. Only a few of them satisfied the warrants specified. The following locations were selected, the physical data of which are given in Table 7. Figure 1 shows the five locations on a road map of Indiana.

TABLE 7

SPEED STUDY LOCATIONS

Location	Urban Area	Highway	Approach to the Urban Area	Direction of Study	ADT
A	West Lafayette	U.S. 52	North	Southbound Northbound	4600-5500
B	West Lafayette	Ind. 43	North	Southbound	2800-4300
C	Logansport	U.S. 35	South	Northbound	3500-4100
D	Peru	U.S. 31	North	Southbound	4100-4300
E	Wabash	U.S. 24	East	Westbound	4300-4500



STUDY LOCATIONS

FIGURE 1

Location A.

Among all the five locations this one was chosen for the most comprehensive study due to the fact that, in the fall of 1958, the highway had been reconstructed from a two lane facility to a four lane one. No speed limits had been posted since the completion of the reconstruction. Permission was obtained from the State Highway Department of Indiana to utilize this highway for extensive signing research.

The highway, U.S. 52 Business Route, starting at the intersection of U.S. 52 and U.S. 52 Bypass north of West Lafayette, penetrates the downtown area of the cities of West Lafayette and Lafayette. From the intersection referred to above to Lindberg Road, a distance of 3,800 feet, the highway is a four lane divided facility with a 30 foot wide grass median on the first 1,000 feet, and a narrow concrete median of 5 foot width on the remaining 2,800 feet. The lane width is 12 feet. On the west side of the highway are golf courses, on the east side some development, a drive-in-theater and a smaller residential area. The development is not closely situated to the highway. Subsequently, the effect of this development upon the speed was deemed negligible. From Lindberg Road and towards the center of West Lafayette the highway has four undivided lanes, 12 foot wide, and runs through a highly developed residential area with development literally to the curb. From Northridge Drive sidewalks exist. The test section of this highway is approximately 9,000 feet long, from the U.S. 52 Bypass intersection to the Purdue University Fieldhouse. 3,800 feet runs through a primarily undeveloped area, and 5,200 feet through a highly developed residential area. The border between these two areas is very distinct, following

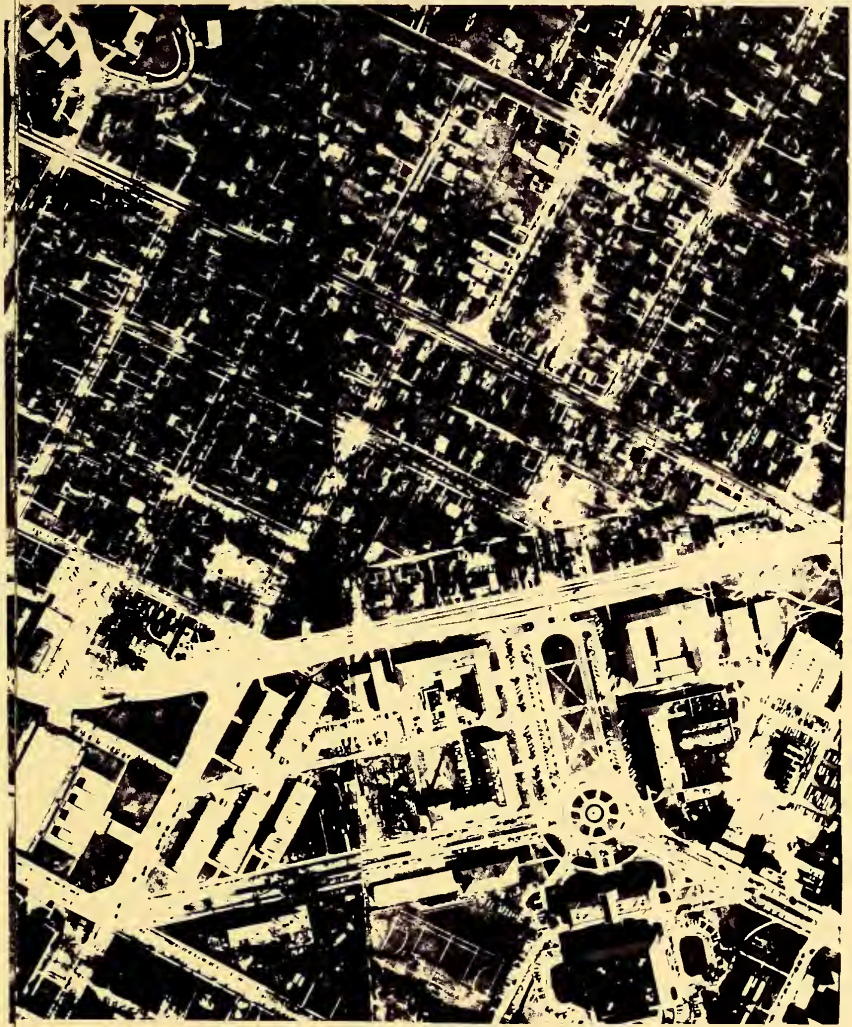
Lindberg Road in an east-west direction. Along 1,600 feet, between Hillcrest Road and Victory Drive, there is a 3 per cent grade, downward in the southbound direction. At Northridge Drive and at the fieldhouse there are two curves with 1,000 foot and 400 foot radii, respectively. It is quite obvious that the latter curve will affect the speed considerably. Accordingly, no studies were carried out beyond this curve. Moreover, about 300 feet beyond the curve is a signalized intersection which is not visible before entering the curve. An aerial photograph of the entire test area is shown on Figure 2.

Location B.

State Road 43 parallels the Wabash River at the north approach of West Lafayette. The lack of distinctive development along the highway in the river valley is noteworthy. Because of topography and frequent flooding only a few houses are actually situated alongside the highway. The study section comprised about 4 miles of length. The road width is 20 feet. Speed limits are assigned and include a 50, a 40, and a 30 mile per hour zone. The 50 mile per hour zone is about 3 miles long, the 40 mile per hour zone comparatively short, 300 feet, and the 30 mile per hour zone about 500 feet. A curve with 600 foot radius follows immediately beyond the 40 mile per hour sign in the inbound direction.

Location C.

The suburban development along the south approach of U.S. 35 into Logansport consists primarily of some residential development on the west side, and on the east side a stock yard, a cafeteria and a miniature golf course, a combination of industrial and commercial development.



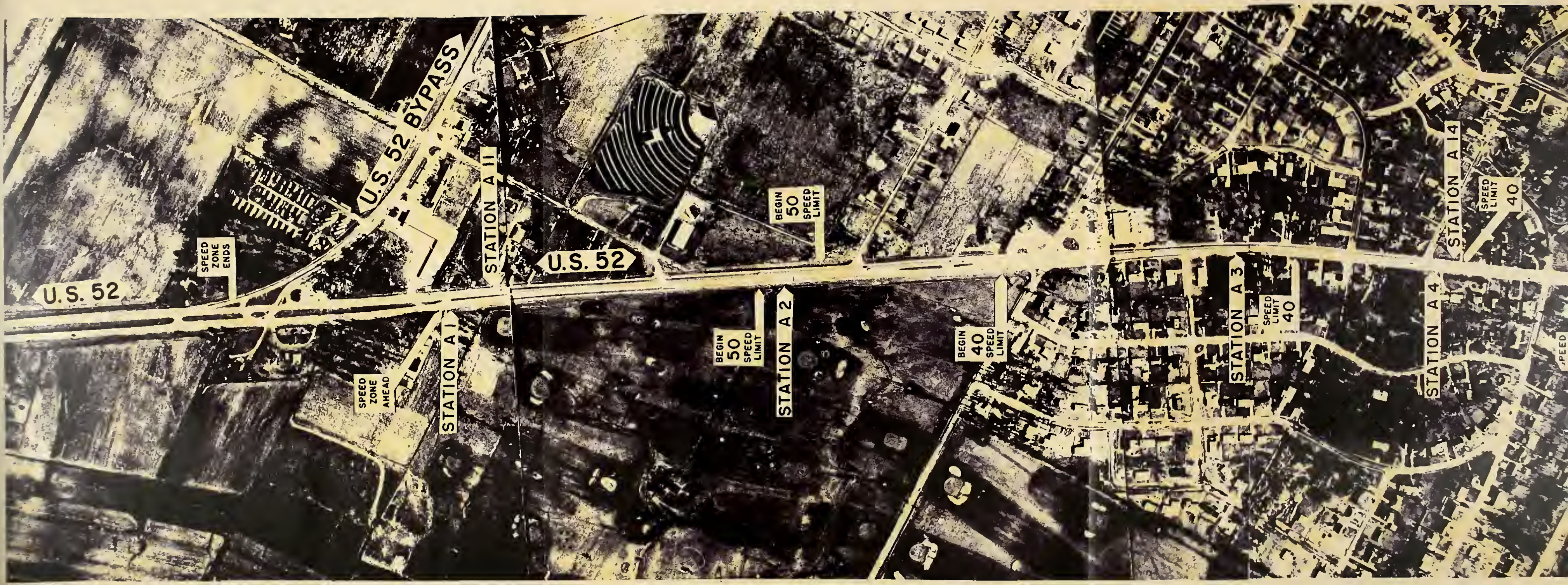


PHOTO MOSAIC OF LOCATION A

FIGURE 2

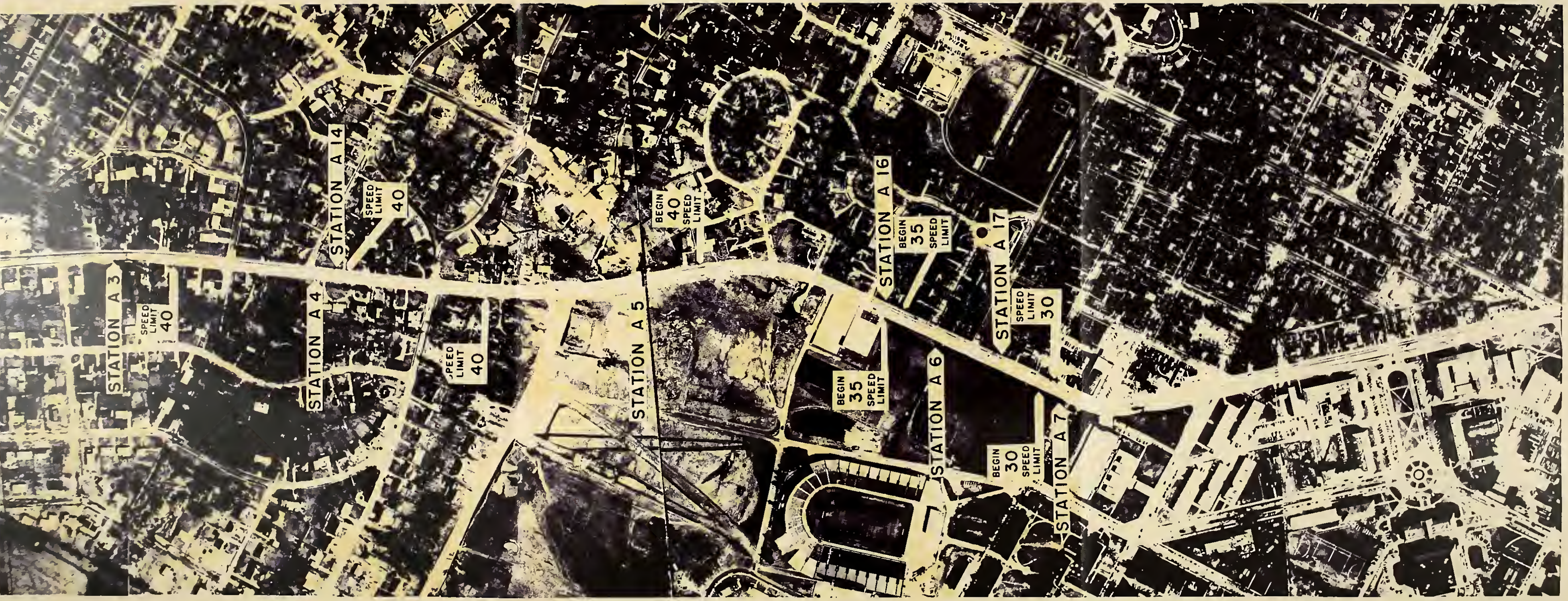


PHOTO MOSAIC OF LOCATION A

FIGURE 2

The roadway has two lanes, each one 12 foot wide. The study area comprised about one mile of length, including a 40 mile per hour and a 30 mile per hour speed zone.

Location D.

The development along the north approach of U.S. 31 into Peru is mainly commercial. The highway is perfectly straight, and the city is visible at a distance of more than a mile before reaching the city limits which coincide with the 30 mile per hour speed limit. A 40 mile per hour zone also exists for a distance of about 2,000 feet.

Location E.

Along the east approach of U.S. 24 into Wabash the development is entirely industrial, a chicken farm, a state highway garage, factories. From the 40 mile per hour speed limit sign the highway is [illegible] straight and the city visible. The roadway has two, 12 foot wide, lanes. At the city limit a 30 mile per hour zone starts.

The locations A and B are specific and cannot be compared to any other location because of design features such as number of lanes, lane width, and also because of specific roadside development. Moreover, the study area for location A penetrates rather deep into the urban development. On the other hand, locations C, D, and E are similar in design characteristics except for the roadside development. Accordingly, the influence of roadside development upon the speed may or may not be significant.

Speed Measurement Stations

It is extremely important that the obtained speed data reflect the true speed of the vehicles. The drivers should not have the slightest feeling that their speed is being checked. If he has this feeling he doubtlessly will reduce speed, particularly when a speed limit is knowingly exceeded.

At every location selected a thorough detailed study was made in order to find suitable sites for measurement stations. The necessity of hiding the equipment as well as the recorders was urgent and each station had to provide an unobstructed view of the highway so as to be able to classify the passing vehicles by reading the license plates. Moreover, measurement stations should not be located too far beyond an existing speed limit sign if the effect of that sign was going to be studied. By using an artificial mailbox in which the transmitter was hidden and a panel truck, provided by Purdue University, as the recording site it was hoped to attain optimum reduction of the drivers' suspicion. It was also assumed that a relatively large number of vehicles exceeding the actual speed limit during the speed check would indicate little or no suspicion.

Table 8 briefly shows some physical data for the various speed measurement stations. Figures 3 - 8 picture the locations, generally viewed from the exact site of the stations. In cases where a speed limit sign is perceptible in the picture the site is situated immediately beyond the sign. An aerial photograph of the entire location A with all signs and measurement stations shown is Figure 2.

Because of the construction of a new bridge over the Wabash

TABLE 8

DATA RELATED TO SPEED MEASUREMENT STATIONS

Location	Measurement Station No.	Direction	Speed Limit Sign Checked	Figure No.
A	1	Inbound	SZA*	2, 3
	2	"	50	2, 3
	3	"	40	2, 3
	4	"	40	2, 3
	5	"	40	2, 3
	6	"	35	2, 3
	7	"	30	2, 4
	11	Outbound	50	2, 4
	14	"	40	2, 4
	16	"	35	2, 4
	17	"	30	2, 4
B	1	Inbound	65	5
	2	"	SZA	5
	3	"	50	5
	4	"	50	5
	5	"	40	5
	6	"	30	-
C	1	Inbound	65	6
	2	"	40	6
	3	"	30	6
D	1	Inbound	65	7
	2	"	SZA	7
	3	"	40	7
	4	"	30	7
E	1	Inbound	SZA	8
	2	"	40	8
	3	"	30	8

* SZA = Speed Zone Ahead.

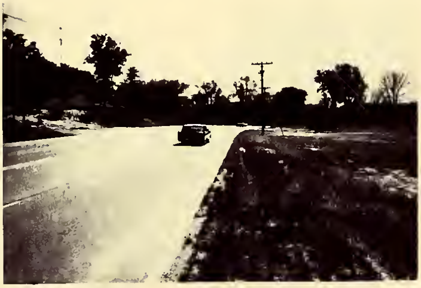
river station B6 could not be studied. Heavy construction equipment, excavation, and some other factors contributed to a general reduction of the speed of the vehicles passing that area.

STATION A 1

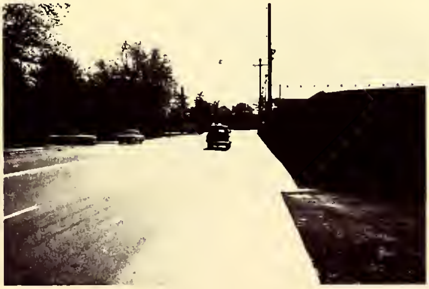
STATION A 2

STATION A 3

STATION A 4



STATION A 5



STATION A 6

LOCATION A

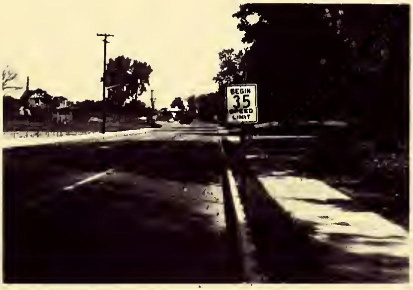
SPEED MEASUREMENT STATIONS

FIGURE 3

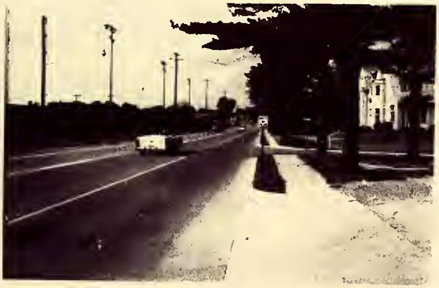
STATION A 7

STATION A 11

STATION A 14



STATION A 16



STATION A 17

LOCATION A

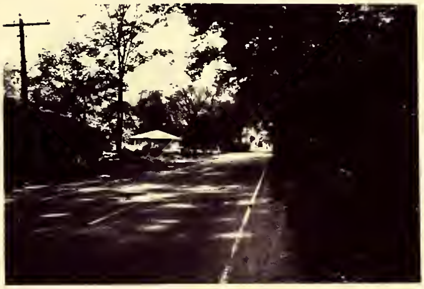
SPEED MEASUREMENT STATIONS

FIGURE 4

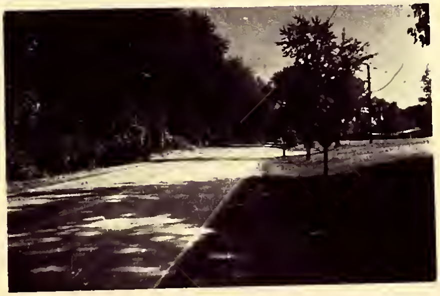
STATION B 1

STATION B 2

STATION B 3



STATION B 4



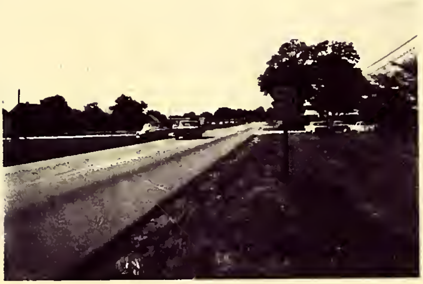
STATION B 5

LOCATION B

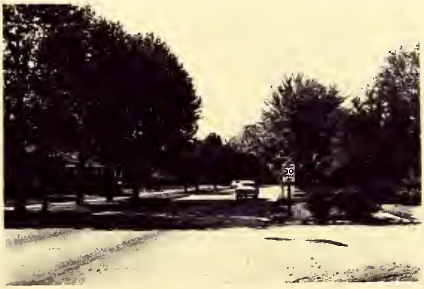
SPEED MEASUREMENT STATIONS

FIGURE 5

STATION C 1



STATION C 2



STATION C 3

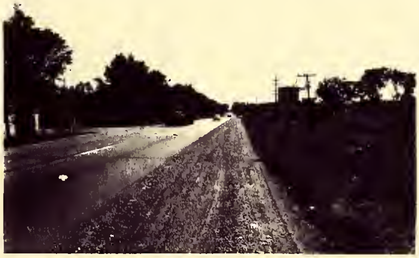
LOCATION C

SPEED MEASUREMENT STATIONS

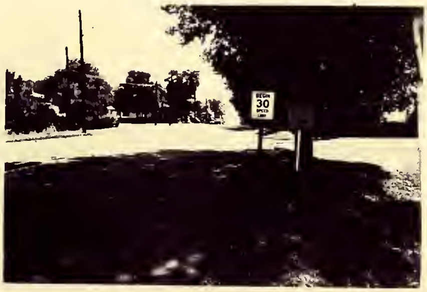
FIGURE 6

STATION D 1

STATION D 2



STATION D 3



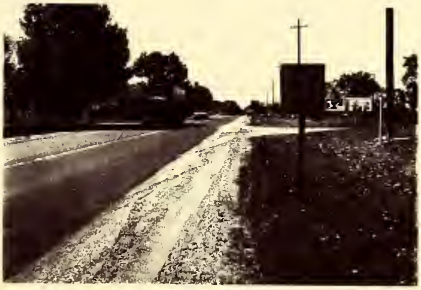
STATION D 4

LOCATION D

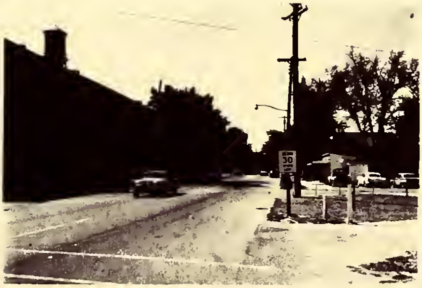
SPEED MEASUREMENT STATIONS

FIGURE 7

STATION E 1



STATION E 2



STATION E 3

LOCATION E

SPEED MEASUREMENT STATIONS

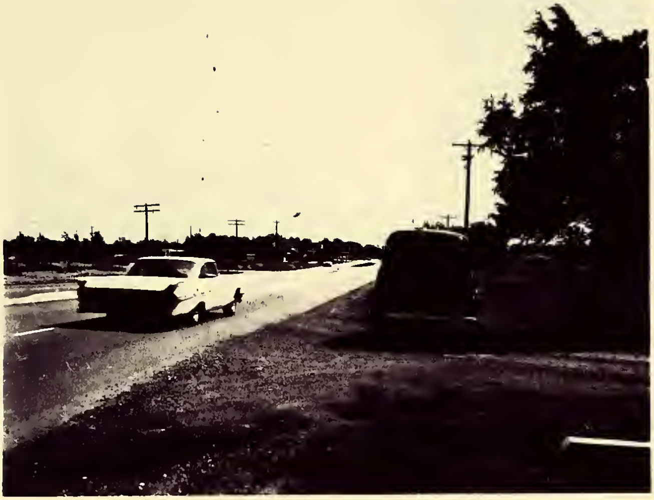
FIGURE 8

EQUIPMENT

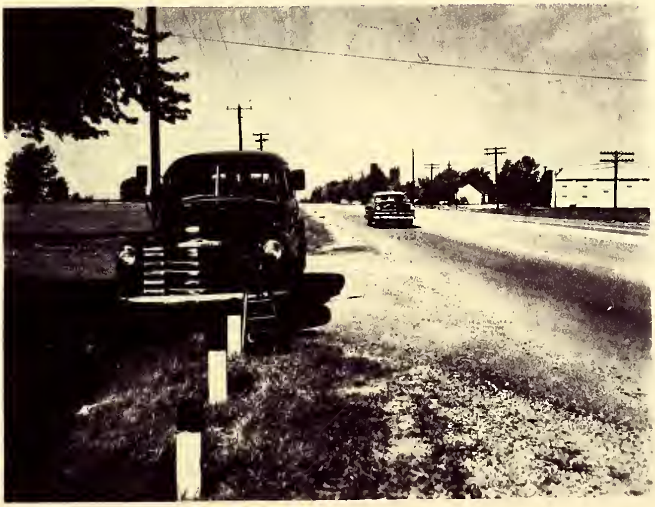
All speed data for this study were obtained by the use of an Electro-Matic speed meter powered by a 12 volt automobile storage battery. This meter belonged to the Joint Highway Research Project.

The radar meter utilizes the Doppler effect to measure speeds. Radio waves of constant frequency are broadcast by the transmitter-receiver in a cone shaped beam about 20 degrees wide. When reflected from a moving object these waves change frequency in proportion to the component of speed in the direction of the waves. The difference in frequency between the transmitted waves and the waves reflected back to the unit induces a potential that is read on the indicator, a voltmeter calibrated in equivalent miles per hour.

The effective range of the meter increases with its height above the roadway, the optimum height being about three feet. In order to achieve this height and facilitate aiming, the unit was usually supported on a wooden stool which was levelled by means of stakes laid flat beneath the legs (Figure 9). However, at some locations the unit had to be set in a higher position, approximately 5 feet above the ground, because of the use of an artificial mail box in which the unit was inserted (Figure 10). On the other hand, at a few locations the unit was set up only 1.5 feet above the ground. The main reason for this variation of position height was the ultimate necessity of



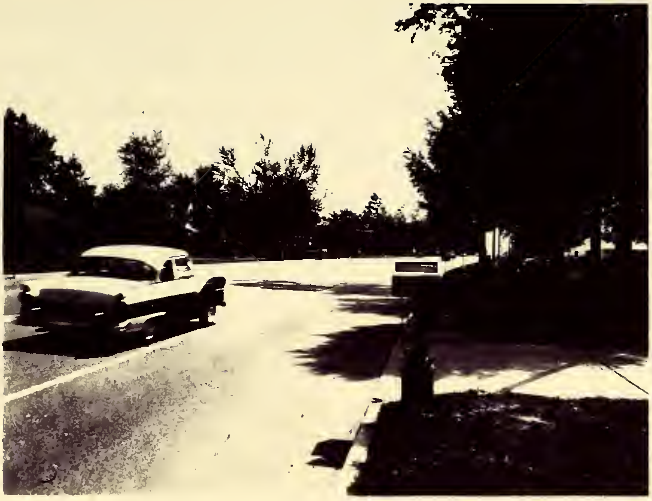
DRIVER'S VIEW



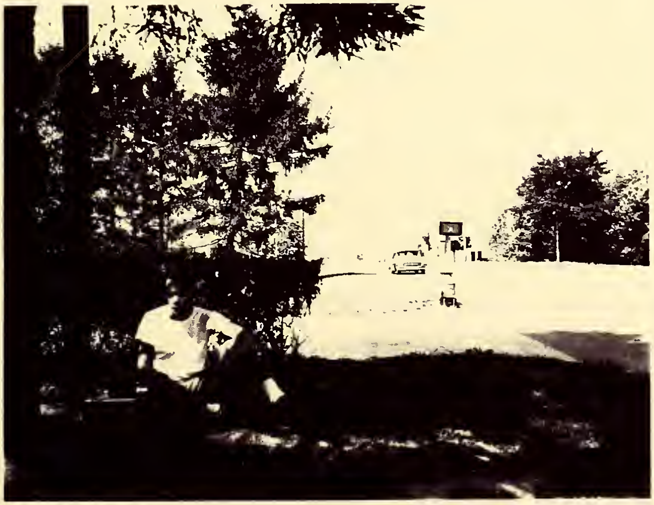
RECORDING SPEED

RADAR SPEED METER SETUP

FIGURE 9



DRIVER'S VIEW



RECORDING SPEED

RADAR SPEED METER SETUP

FIGURE 10

concealing the equipment thus avoiding suspicion and curiosity which might have caused a deliberate reduction of the traveled speed. Test runs with a Purdue vehicle equipped with a calibrated speedometer, thus providing "true" speeds, indicated no significant difference between the true speed and the meter registered speed due to the variations in height positions of the unit, at least for the actual speed range, 20 to 70 miles per hour.

The meter registers the speed of the vehicles in the beam, traveling either towards or away from the unit, to an accuracy of one to two miles per hour. However, since the range of the beam for passenger cars is only about 100 to 150 feet, depending upon the strength of the impulse, certain errors may enter into the indicated reading (75).

Meter readings were affected by the lateral position of the unit because of the necessity of setting the meter back from the pavement edge in order to minimize any effect its presence might have on traffic approaching the control station. The beam, therefore, had to be angled into the traffic stream. As a result, the indicator readings represented only a component of the true vehicle speeds. Furthermore, passenger cars in the far lane would be within range only while intersecting the beam at a comparatively large angle. Due to the fact that the main part of this study was concerned with a four lane road, Northwestern Avenue in West Lafayette, Indiana, special precautions had to be taken regarding the accuracy of the registered speed of cars in the inner lane.

A mathematical relationship of the location of the radar unit with respect to the roadway and speed and which is comprised of two simultaneous equations can be developed:

$$y = S \tan(\beta + 10^\circ) - w,$$

$$\cos \beta = \frac{V}{V + e},$$

where y = lateral distance in feet from radar unit to road edge

S = effective range in feet

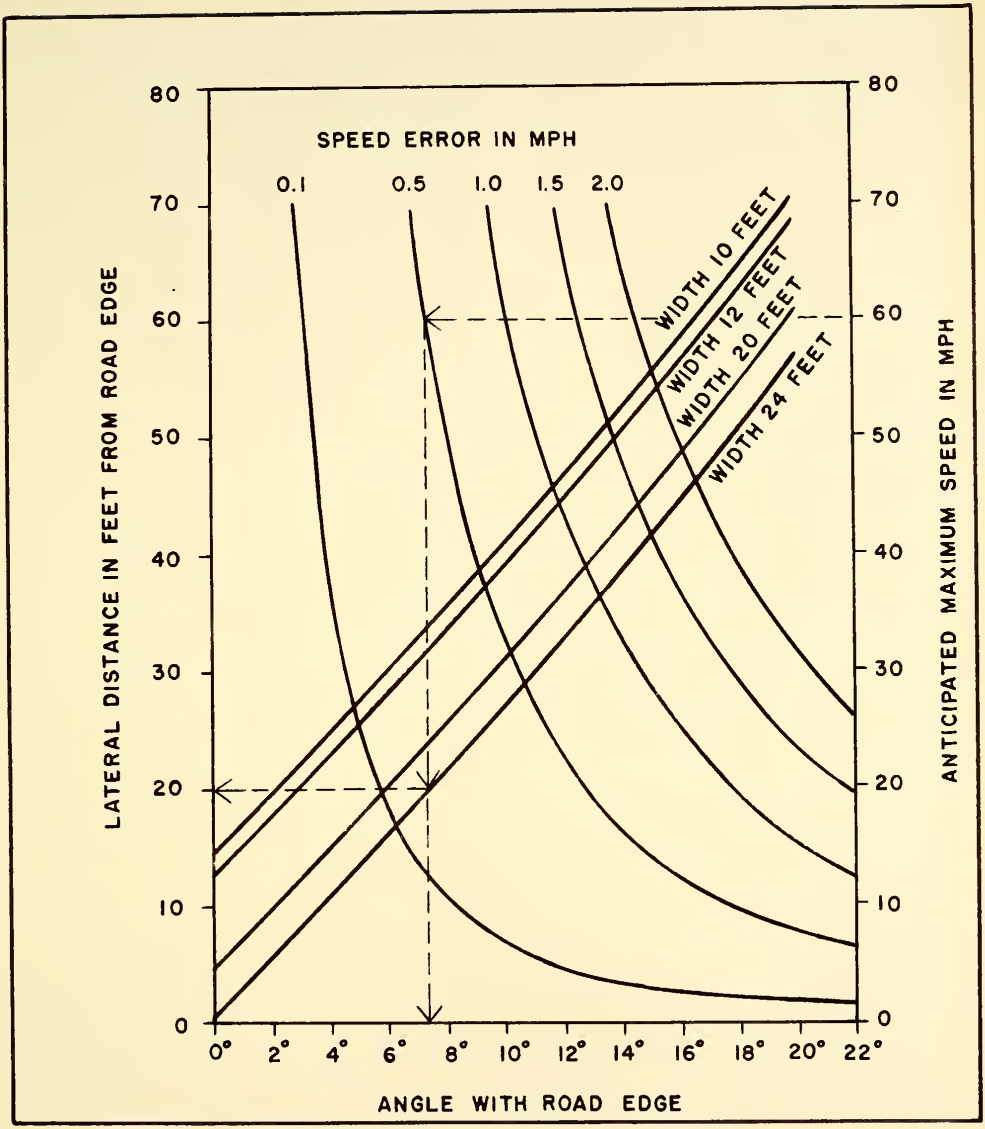
β = angle in degrees with road edge

w = width in feet of lane or roadway, respectively

V = measured speed in miles per hour

e = speed error in miles per hour

Several studies indicated that the average effective range for passenger vehicles was 140 feet. A graphical representation of this relationship is given in Figure 11. An illustrative example explains the use of this chart for selecting a proper position of the radar unit. The radar meter measures a component of the true speed, and first, the maximum allowable speed error must be decided. For example, a speed error of 0.5 mile per hour indicates that the true speed is 40.5 miles per hour when the measured speed is 40 miles per hour. It must be borne in mind that the total allowable error is comprised of the angular speed error and the statistical error, the size of which depends upon sample size and dispersion. The latter error may be of substantial size, and, therefore, the speed error should be kept as small as possible. In the usual situation, one wants to know where to place the radar unit in order to measure the speed unidirectionally for two 12 foot lanes of a four lane undivided highway, and, at the same time, avoid interference of vehicles traveling in the opposite direction. Anticipating a maximum speed of 60 miles per hour at the station studied and a speed error



POSITION OF RADAR SPEED METER

FIGURE 11

of maximum 0.5 mile per hour the unit may advantageously be placed 20 feet from the road edge and angled about 7 degrees with the road edge, in accordance with Figure 11. Any combination of distance and angle along the 24 foot line below this point is also appropriate and results in a speed error less than the presumed 0.5 mile per hour. Exactly the same result is obtained if one wishes to record speed in both directions simultaneously on a 24 foot wide road. In general, the closer the radar meter is to the edge the less is the speed error. During this entire study the radar unit was placed and concealed as close to the road edge as practicable in order to substantially limit the angular error.

Meter readings were also affected by the charge in the batteries. More than five hours continuous operation was sufficient to discharge the batteries to the point where they would no longer be reliable. Since the longest continuous operation usually lasted for only three hours whereupon the batteries were recharged no errors due to discharge were encountered.

Test runs with the Purdue vehicle equipped with a calibrated speedometer at speeds from 20 to 70 miles per hour, in increments of ten miles per hour, were performed at the beginning and the end of the study. There was no indication of any difference between the readings, neither between the two test occasions nor between the indicated and the true speed, although the meter had been used for about 500 hours between the two tests. A slight difference of 0.5 to 1 mile per hour was encountered for the 60 and 70 mile per hour test runs but the difficulty in sustaining these high speeds exactly might partially explain the difference.

At the beginning of every single speed study a tuning fork was utilized for the calibration of the meter. This tuning fork vibrated at a frequency equivalent to that which would register 60 miles per hour on the indicator.

PROCEDURE

Field

The field procedures for locations B through E were all the same. The equipment was set up on the sites selected and operated during the hours prechosen from the results of preliminary surveys. The speed was measured after the vehicle had passed the transmitter which consequently was directed to transmit the beam in the direction of the traffic flow. This method was regarded superior to letting the traffic approach the transmitted beam, thus obtaining an indicator reading before the vehicle passed. Several factors contributed to this decision, the most important ones being the readiness of hiding the transmitter behind various features and the possibility of reading the license plate and speed of the same vehicle simultaneously, thus increasing the accuracy of recording. It has to be borne in mind that Indiana vehicles only have one license plate. Two recorders were used, one reading the indicator and one reading the license plate. The latter one recorded the speed on a tally sheet, specially prepared for succeeding calculations.

The procedure at location A varied due to the fact that no speed limit signs initially existed. The speeds were first measured at all the stations without any signs posted. On the basis of these surveys the 85th percentile speed was calculated and selected as a warrant for a reasonable speed limit. The 85th percentile speed is generally

agreed to be the most reasonable in establishing a speed zone (48, 68) although one of the purposes of this study was to verify this. A signing plan was made and only one sign was added at a time. A detailed compilation of the various sign conditions are found in Appendix A. The effect of each sign was then studied by speed measurements at all stations which would be affected by it. Because of the great number of measurement stations and sign conditions there was unfortunately not sufficient time to make studies at all the sites for every change in a sign condition. A change in a sign condition consisted of posting an additional sign; with one exception, no signs were removed or changed after once added. Generally, a speed study was performed one or two days before the posting of an additional sign was scheduled. A few days after each new sign was erected the first study was made, and thereafter studies were conducted weekly in order to determine any change in speed by lapse of time.

All day studies in the inbound direction at locations A and B were performed between 1:30 p.m. and 3:00 p.m., all night studies between 8:30 p.m. and 10:15 p.m. In the outbound direction at location A, day studies were carried out between 10:00 a.m. and 11:30 a.m. No night studies were made in this direction, nor in the inbound direction on Friday nights because of variations in travel characteristics (46). Accordingly, no studies were conducted Saturdays and Sundays.

At the other locations, C, D, and E, the time of study varied somewhat due to travel time from Lafayette. However, at all locations speed measurements were taken during off-peak volume hours. The number of free-moving vehicles during peak hour traffic is small, particularly

on two lane highways. At locations B through E traffic was only checked in the inbound direction.

Several attempts were made to read the license plates during the night but had to be characterized as a failure because of inadequate or lack of illumination of the plates on an unexpectedly high percentage of vehicles. Moreover, the visibility decreased rapidly with increasing speed of the passing vehicles.

The total number of passenger vehicles, classified into local and non-local vehicles during daylight, passing each speed measurement station was manually counted and divided into two groups, one comprising the vehicles for which speed was checked and the other comprising the vehicles which, for various reasons, could not be checked. Vehicles of the latter type were either braking, turning, passing or going to perform such maneuvers and consequently could not be regarded as free moving.

As previously mentioned local vehicles were those carrying prefix letters assigned to the county in which the speed study was carried out. Table 9 lists these prefixes for the various counties.

Office

The data recorded on a field tally sheet were reworked, summarized, and transferred to a form specially designed to facilitate the first step of the statistical analysis, which comprised calculation of mean speed, median speed, 85th percentile speed, 15th percentile speed, speed differential, 10 mile per hour pace, and standard deviation. Definitions of statistical terms are given in Appendix A. The second

TABLE 9

PREFIX LETTERS ON INDIANA VEHICLE LICENSE PLATES

Location	County	Prefixes
A	Tippecanoe	MN, MN, MP, MQ
B	Tippecanoe	MM, MN, MP, MQ
C	Cass	SS, ST
D	Miami	ZX, ZY, ZZ
E	Wabash	VA, VB

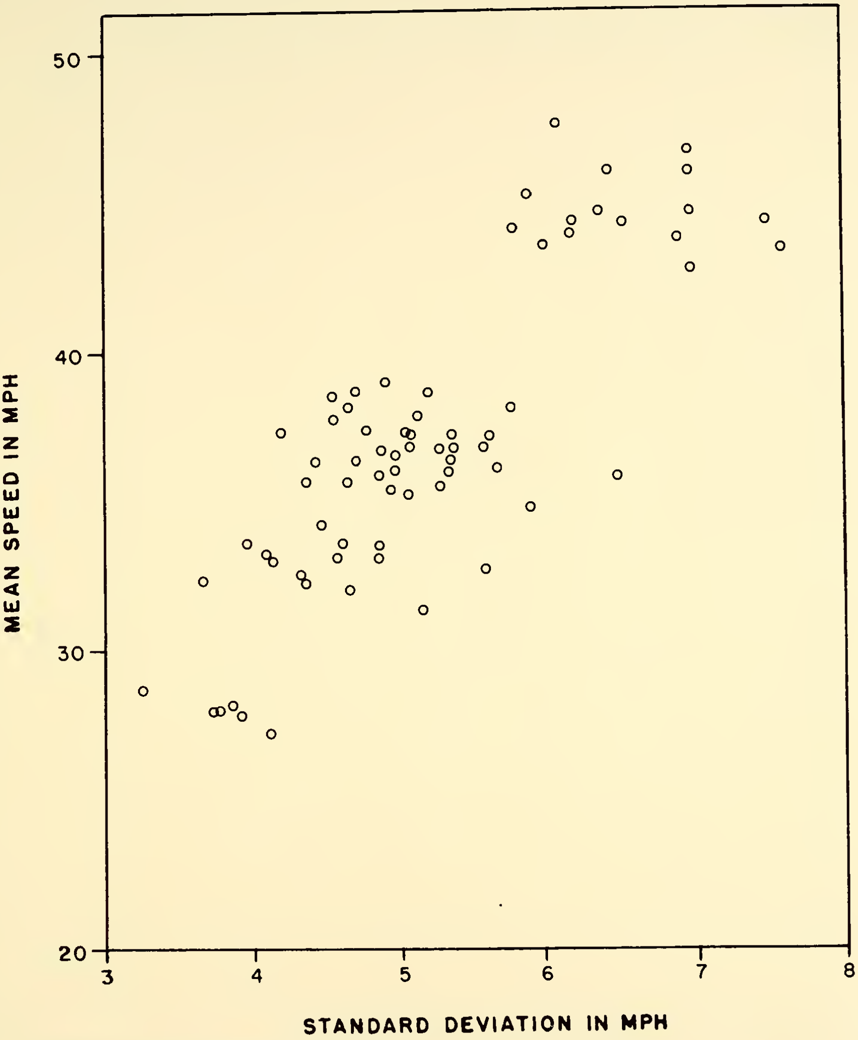
step was filing all calculated data by various influencing factors in tables (Appendix B). The third and last step was the analysis of the data in Appendix B by using diverse statistical methods and inferences, epitomized in Appendix C. An illustrative example of the calculations is also carried through in this appendix.

STATISTICAL ANALYSIS

Analysis of Speed Parameters

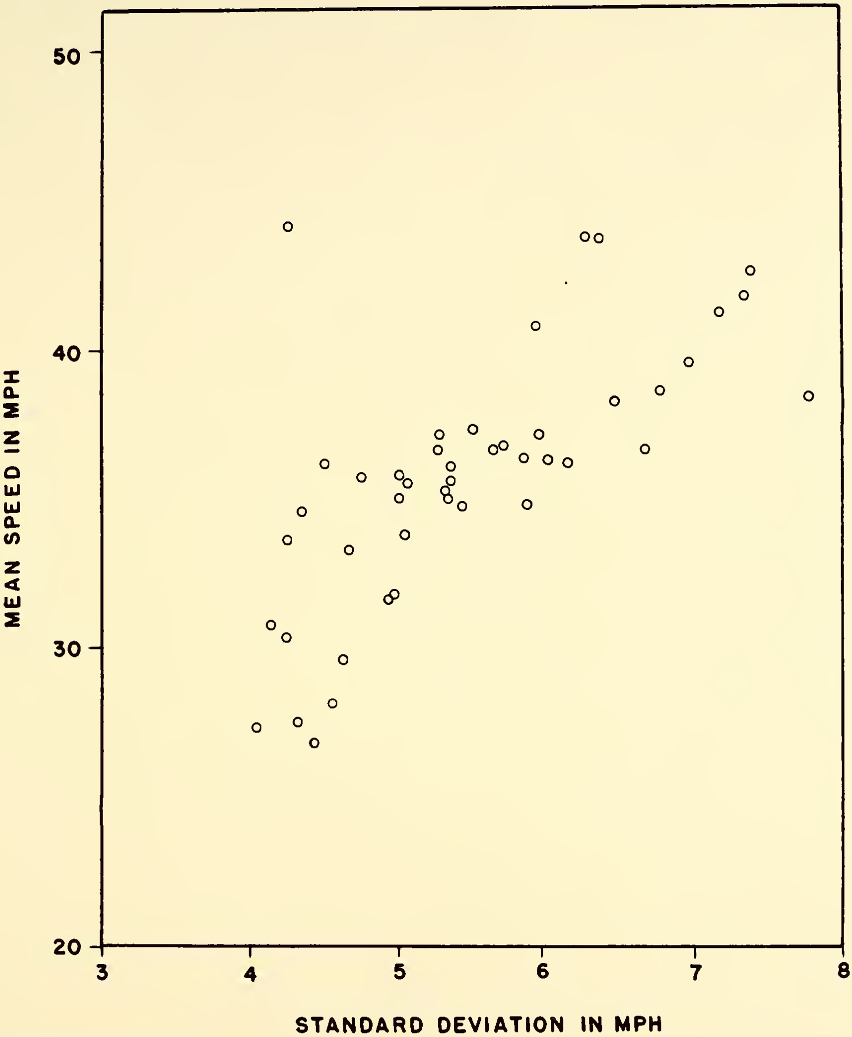
The field data were processed to yield values of speed parameters for each station by sign condition, residence of vehicle, and time of study (day or night). These parameters were a measure of two characteristics of the speed distribution: the magnitude and the dispersion. The parameters of magnitude were the mean speed, the median (or 50th percentile) speed, and the 15th and 85th percentile speed; those of dispersion were the variance (or square of the standard deviation), the speed differential and the pace.

Since the speed differential and, consequently, the standard deviation were expected to be larger in an area where a high speed was permitted than in one with a lower speed allowed, the first phase of the analysis consisted of an investigation of the homogeneity of the variances. Accordingly, standard deviations were plotted against mean speeds for day and night conditions, shown in Figures 12 and 13, respectively. It is evident that a relationship exists between mean speed and standard deviation, hence indicating heterogeneity of the variances. In analyzing the data the statistical method termed "analysis of variance" (ANOVA) was utilized. The following basic assumptions related to the data are connected with this method and govern its usefulness: additivity of effects, normality of errors, independence of



SCATTER DIAGRAM OF STANDARD DEVIATION AND MEAN SPEED AT LOCATION A (DAY)

FIGURE 12



SCATTER DIAGRAM OF STANDARD DEVIATION
AND MEAN SPEED AT LOCATION A (NIGHT)

FIGURE 13

errors, and homoscedasticity (homogeneity of variances). The obvious heterogeneity would therefore indicate a limitation in utilizing the ANOVA, although the method is relatively insensitive to this factor compared to other ones. One method to diminish the influence of heteroscedasticity is transformation, which basically means a conversion of every original single speed measurement to some mathematical function of the same speed depending upon the kind of relationship existing between mean speed and standard deviation. Then the whole procedure has to be repeated; the transformed speed parameters are calculated and with these new data analysis of variance can be performed. A proper transformation would be logarithm of the speed.

The method just described is tedious and was not utilized in this case. From the figures 12 and 13 three distinctive clusters can easily be distinguished, each one related to one or more characteristic speed measurement stations. Consequently, the ANOVA method can be utilized for all factors affecting the speed at each individual measurement station. It is quite obvious from the scatter diagrams that there is a significant difference in speed between the measurement stations. The variations between the measurement stations were found to be far above the 5 per cent significance level.

Provisions could have been made for taking the same number of measurements for each sign condition at each individual station in order to simplify the analysis, i.e., the same number of replications per cell. The large number of conditions and stations and the limited amount of time, however, required variation in the number of replications; at some stations only one measurement was taken for some of the

most important sign conditions, at other stations several measurements were taken for the same sign condition. The reason for the latter case was to determine whether or not a lapse of time would cause any change in the speed pattern, and a few of the stations were chosen as control stations.

Because of the unequal number of replications per cell a special method was used to obtain only one replication and eventually make corrections for it in the analysis. The method is as follows (86):

Let X_i = calculated variable, either average speed $\overline{V}$ or 85th percentile speed, V_{85}

n_i = number of vehicles on which the value of X_i is based.

i = 1, 2, . . ., g replications per cell

k = number of cells

The first step is to calculate the weighted average, $\overline{X}$, given by

$$\overline{X} = \frac{\sum_{i=1}^{g} n_i X_i}{\sum_{i=1}^{g} n_i}$$

The second step is to calculate the sum of squares, SSg, within an individual cell, given by

$$SSg = \sum_{i=1}^{g} n_i X_i^{2} - \frac{\left[\sum_{i=1}^{g} n_i X_i\right]^2}{\sum_{i=1}^{g} n_i}$$

Using an automatic or a semi-automatic calculator the following expression facilitates the calculations,

$$SSg = \sum_{i=1}^{g} n_i X_i^2 - \bar{X} \sum_{i=1}^{g} n_i X_i$$

If this sum of squares is divided by (g - 1), the degrees of freedom, an estimate is obtained of the mean square, MSg, based on individual measurements,

$$MSg = \frac{SSg}{g - 1}$$

The third step is to calculate the total sum of squares, SSk, within all cells, given by

$$SSk = \sum_{k} SSg$$

Dividing SSk with the sum of the degrees of freedom for each cell an estimate is procured of the mean square, MSk, based on individual measurements,

$$MSk = \frac{SSk}{\sum_{k} g - 1}$$

The fourth and last step in the procedure is to calculate the error mean square, MSe, which primarily is a correction of MSk because of the reduction of the replications within the cells,

$$MSe = \frac{MSk}{\bar{n}}$$

$\bar{n}$ is the harmonic mean of all the n_i's within the cells, the harmonic mean defined by

$$\bar{n} = \frac{1}{\frac{1}{k} \sum_{k} \left[\frac{1}{\sum_{i=1}^{g} n_i} \right]}$$

In the ANOVA table (see Appendix C) the error mean square is MSe and the degrees of freedom are $\sum_{k} (g - 1)$.

Using this method one has to bear in mind the general relationship between the standard deviation of the distribution of sample means and the standard deviation of the population, defined by

$$\sigma_{\bar{x}} = \frac{\sigma}{\sqrt{n}}$$

This relationship is confined solely to the distribution of sample means. For the distribution of sample percentiles the following relationship exists,

$$\sigma_p = K_p \cdot \frac{\sigma}{\sqrt{n}}$$

where

$$K_p = \frac{\sqrt{p(1-p)}}{f(\xi)}$$

For a given fraction p or percentile, i.e., $P = 100p$, the values of $f(\xi)$ and K_p are given in Table 10.

TABLE 10

CORRECTION FACTORS FOR PERCENTILES

p	$f(\xi)$	K_p	K_p^2
0.50	0.3989	1.253	1.5700
0.75	0.3178	1.362	1.8550
0.80	0.2800	1.429	2.0420
0.85	0.2330	1.533	2.3501
0.90	0.1754	1.710	2.0241

Accordingly, the standard deviation of the distribution of the 85th percentile speeds is defined by

$$\sigma_{85} = 1.533 \cdot \frac{\sigma}{\sqrt{n}}^{*}$$

Using the method of calculating the error mean square, previously outlined, the precise expression for the MSe is

---

* The variance of the distribution of the 85th percentile speeds is defined by

$$\sigma_{85}^2 = 2.3501 \cdot \frac{\sigma^2}{n}$$

Parameter	MSe	Degrees of Freedom
Mean Speed	$\frac{MSk}{\bar{n}}$	$\sum_{k} (g - 1)$
85th Percentile Speed	$\frac{1}{2.3501} \cdot \frac{MSk}{\bar{n}}$	$\sum_{k} (g - 1)$

This method yields reliable results as long as the variations within the cells are small. If the variations are great the SSg becomes substantial and consequently MSe increases reducing the possibilities of exhibiting significant results. Although the data, in terms of weighted means, may look conspicuously significant at a first glance, the variations within the cells may be of such a magnitude that there is even a significant difference between data within the cells. In the rare case of this type, the analysis probably will not yield significant differences between factors expected to do so thus indicating that the weighted means are not reliable.

Analysis of Speed Violations

This part of the analysis deals solely with vehicles exceeding the posted speed limits by 5 miles per hour or more, generally regarded as the enforcement level (59). Because the variables in this analysis are fractions, analysis of variance cannot be utilized directly. A procedure of transforming the data must first be introduced. The following notations are used:

m = the number of vehicles exceeding the posted speed limit by

5 miles per hour or more for a particular sign condition

$n =$ the number of vehicles passing the posted speed limit for a particular sign condition

$g =$ the number of measurements (replications) for a particular sign condition

The fraction z is defined by

$$z = \frac{m}{n}$$

Analysis of variance can then be carried out with a transformed variable u defined by (82)

$$u = 2 \text{ arc } \sin \sqrt{z}$$

With an unequal number of replications per cell the same method can advantageously be utilized as has been previously outlined for pure speed data. Table 14 in Appendix B deals with all the transformed data and gives the values of z and u for each condition.

A tabulated summary of the results of the entire statistical analysis in terms of significant or insignificant changes for the various sources of variation is given in Table 11.

TABLE 11

SUMMARY OF STATISTICAL ANALYSIS

Source of Variation	Station A 1			Station A 2		
	$\bar{V}$	V_{85}	u	$\bar{V}$	V_{85}	u
Condition c(v)	NS	NS	NS	NS	NS	NS
Vehicle v	NS	NS	NS	NS	NS	NS
Interaction c x v	NS	NS	NS	NS	NS	NS
Condition c(t)	NS	NS	NS	NS	NS	NS
Time t	NS	NS	NS	S	S	NS
Interaction c x t	NS	NS	NS	S	NS	NS

Source of Variation	Station A 3			Station A 4		
	$\bar{V}$	V_{85}	u	$\bar{V}$	V_{85}	u
Condition c(v)	NS	NS	NS	S	NS	NS
Vehicle v	S	S	NS	S	S	NS
Interaction c x v	NS	NS	NS	NS	NS	NS
Condition c(t)	NS	NS	NS	NS	NS	NS
Time t	NS	NS	NS	NS	S	NS
Interaction c x t	NS	NS	NS	NS	NS	NS

Notations used:

$\bar{V}$	Mean speed	(v)	Vehicle analysis
V_{85}	85th percentile speed	(t)	Time analysis
u	Transformed fraction (see page 57)		
S	Significant change on a 5 per cent significance level		
NS	Insignificant change on a 5 per cent significance level		

TABLE 11 (continued)

SUMMARY OF STATISTICAL ANALYSIS

Source of Variation	Station A 5			Station A 6		
	$\bar{V}$	V_{85}	u	$\bar{V}$	V_{85}	u
Condition c(v)	S	NS	NS	NS	NS	NS
Vehicle v	S	S	NS	NS	NS	NS
Interaction c x v	NS	NS	NS	NS	NS	NS
Condition c(t)	NS	NS	NS	NS	NS	NS
Time t	NS	NS	NS	NS	S	NS
Interaction c x t	NS	NS	NS	NS	NS	NS

Source of Variation	Station A 7			Station A 11		
	$\bar{V}$	V_{85}	u	$\bar{V}$	V_{85}	u
Condition c(v)	NS	NS	NS	NS	NS	NS
Vehicle v	NS	NS	NS	-	-	-
Interaction c x v	NS	NS	NS	-	-	-
Condition c(t)	NS	NS	NS	NS	NS	NS
Time t	NS	NS	NS	-	-	-
Interaction c x t	NS	NS	NS	-	-	-

Source of variation	Station A 14			Station A 16		
	$\bar{V}$	V_{85}	u	$\bar{V}$	V_{85}	u
Condition c	NS	NS	NS	S	S	S

TABLE 11 (continued)

SUMMARY OF STATISTICAL ANALYSIS

Source of Variation	Station A 17		
	$\overline{V}$	V_{85}	u
Condition c	NS	NS	NS

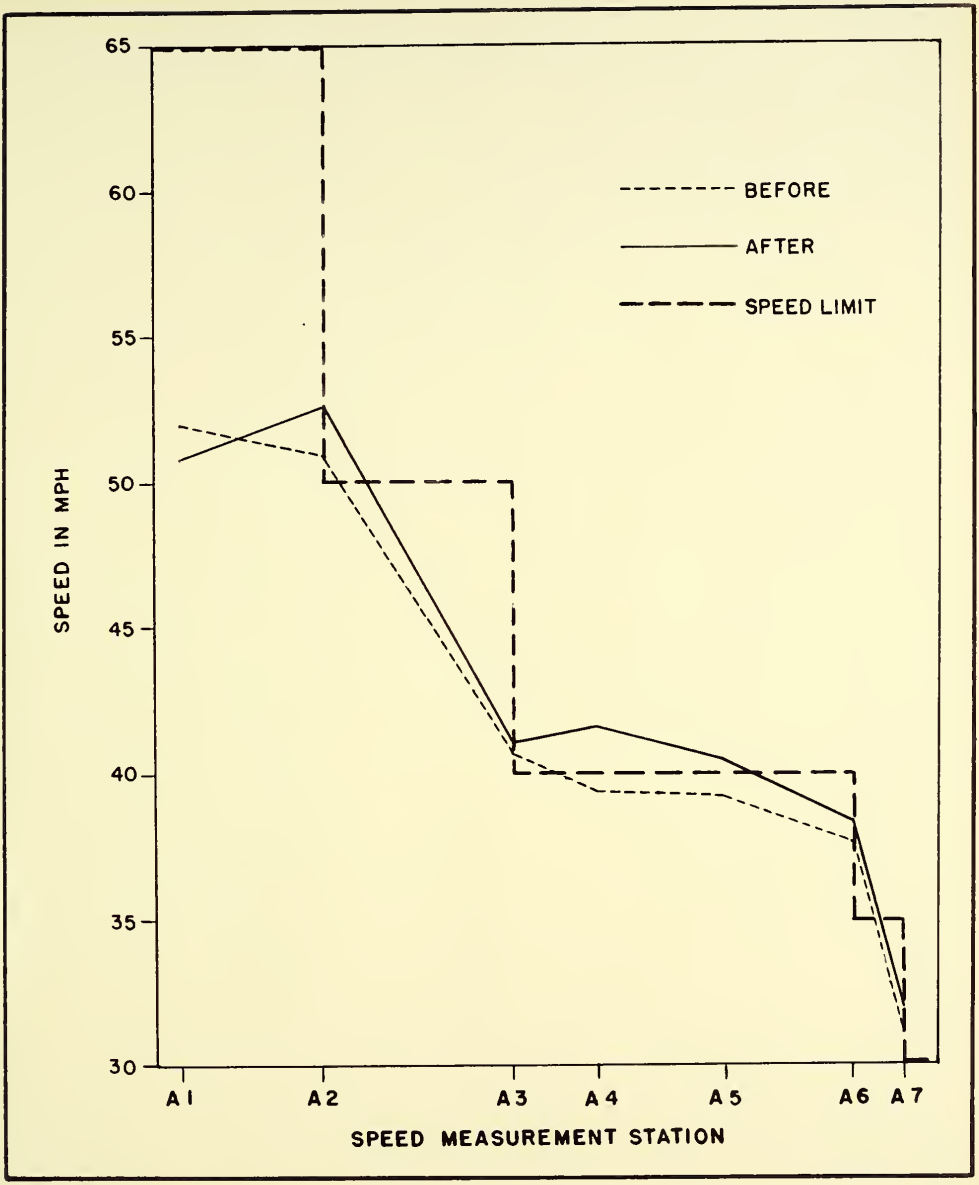
Source of Variation	Locations C, D, and E		
	$\overline{V}$	V_{85}	u
Location L(v)	S	S	S
Condition c(v)	S	S	S
Vehicle v	S	S	S
Interaction L x c	S	S	S
Interaction L x v	NS	NS	S
Interaction c x v	NS	NS	S
Location L(t)	S	S	S
Condition c(t)	S	S	S
Time t	S	S	NS
Interaction L x c	S	S	S
Interaction L x t	S	S	S
Interaction c x t	NS	S	NS

RESULTS

The results obtained by the statistical analysis are briefly outlined in Table 11, showing significant or not significant differences between all the various factors involved. A more detailed analysis of the results for each speed measurement station will be given in this chapter.

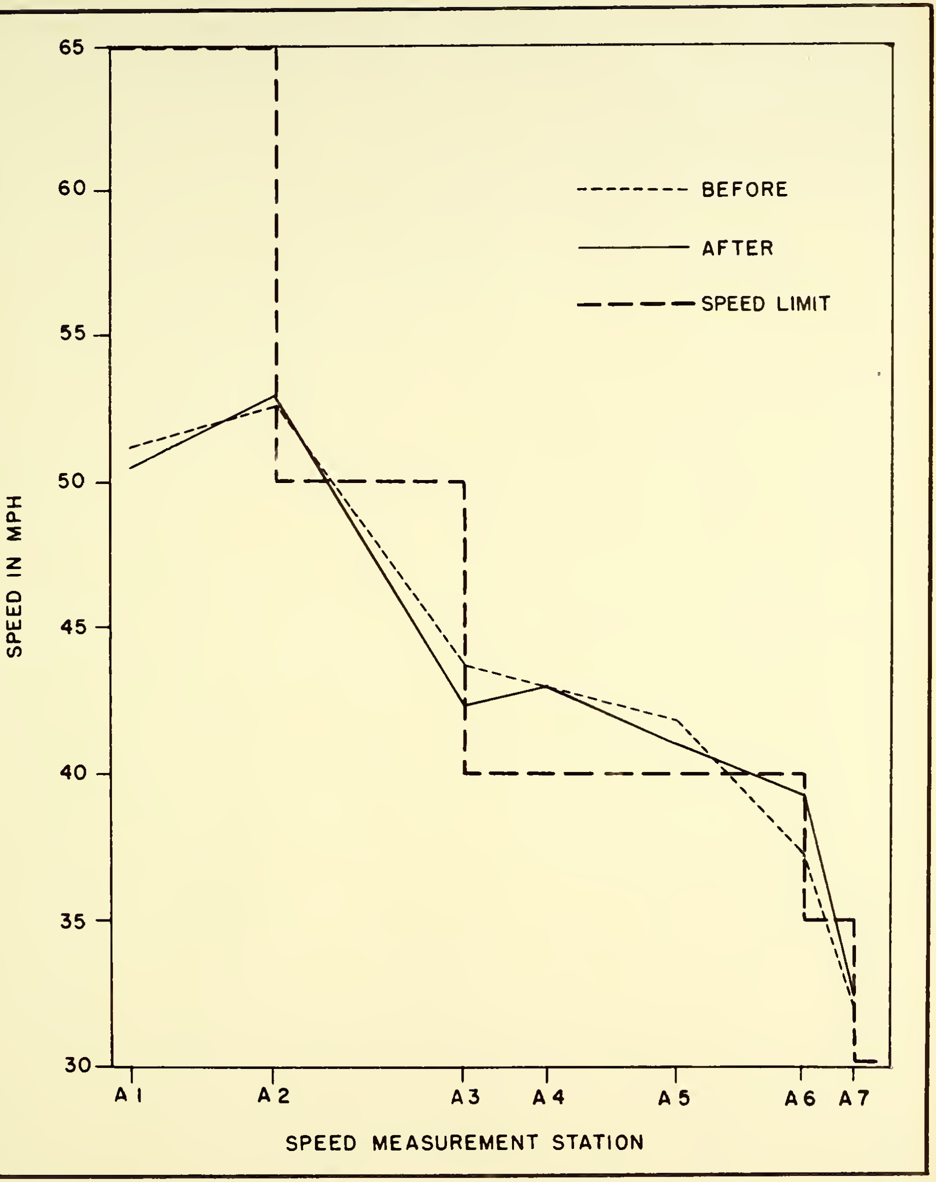
One very important point will be stated before the detailed analysis. The mere absence of speed limit signs in the developed area of location A after the reconstruction of the highway did not establish an abnormal speed pattern.

The general result of posting speed limits on the 85th percentile speed are shown in Figures 14 - 17 for local vehicles, non-local vehicles, day and night conditions, respectively. It may be noted that the speeds of local vehicles (Figure 14) are slightly higher after the posting of the signs. Part or the entire reason may be found in the removal of an uncertainty about what speed limit actually existed along this particular highway. On the other hand, non-local drivers seemed to adjust their speeds slightly closer to the signed condition (Figure 15). Comparing day and night conditions a somewhat closer adjustment seemed to be realized during night, at least for speed limits 40 miles per hour and above. The traveled 85th percentile speed is higher than the posted speed limits at all stations except for A 1, where the "Speed Zone Ahead" sign permits vehicles to travel 65 miles per hour. For



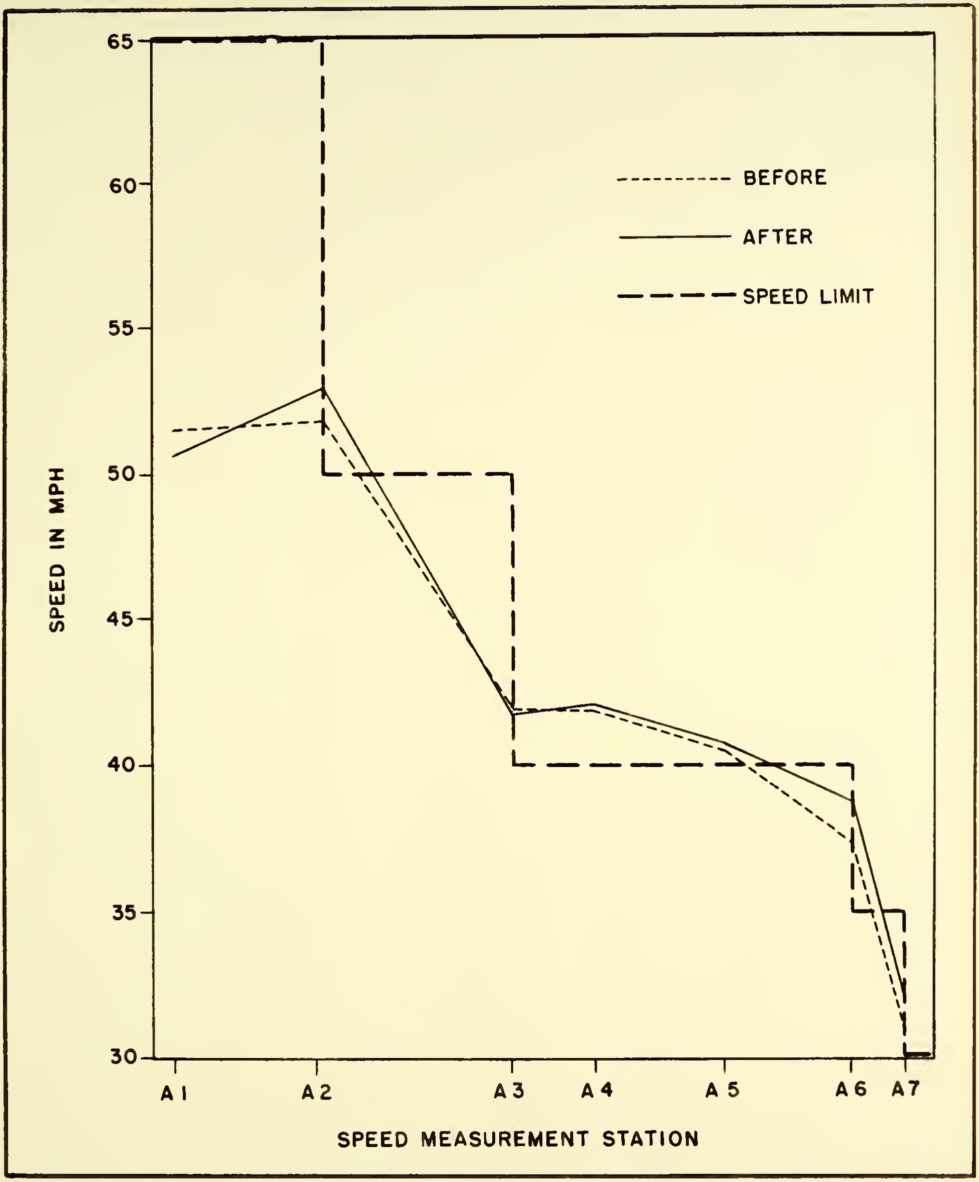
85TH PERCENTILE SPEED BEFORE AND AFTER
POSTING OF SPEED LIMITS
(LOCAL VEHICLES)

FIGURE 14



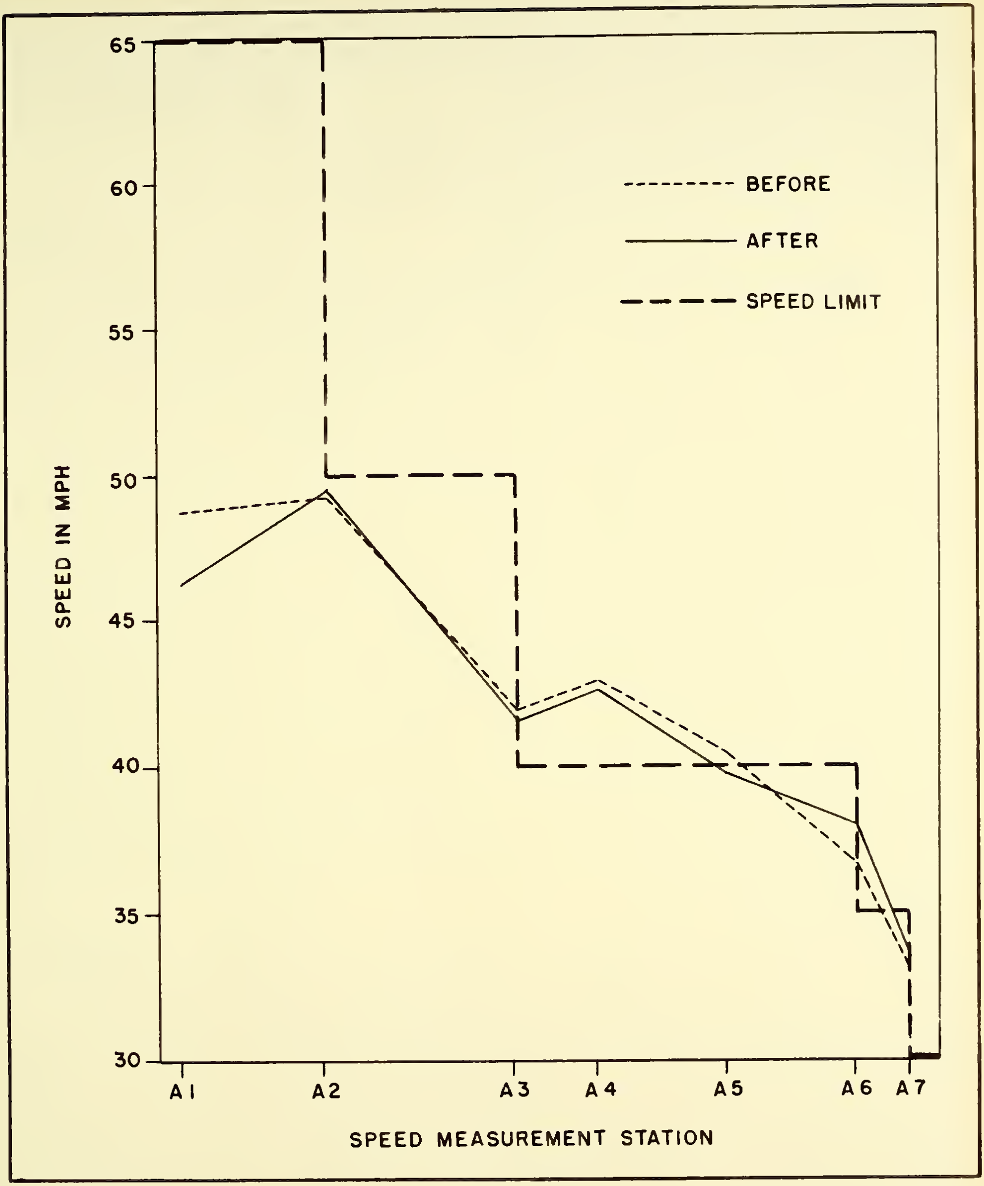
85TH PERCENTILE SPEED BEFORE AND AFTER
POSTING OF SPEED LIMITS
(NON-LOCAL VEHICLES)

FIGURE 15



85TH PERCENTILE SPEED BEFORE AND AFTER
POSTING OF SPEED LIMITS
(DAY CONDITION)

FIGURE 16



85TH PERCENTILE SPEED BEFORE AND AFTER
POSTING OF SPEED LIMITS
(NIGHT CONDITION)

FIGURE 17

night conditions the 50 mile per hour speed limit is slightly above the 85th percentile speed.

Location A

Station A 1

It should be noticed that the within cell variation is considerable for the night condition before the "Speed Zone Ahead" sign was posted. It is difficult to explain these differences because both studies were conducted for the same weather and surface conditions. However, one study was conducted in April, the other one in August. Seasonal variations in the speed pattern may partially contribute to this great difference but it should also be noticed that this difference is not pronounced for the day condition, nor for local and non-local vehicles. The effect of the "Speed Zone Ahead" sign is thus negligible. This is probably due to the fact that the 85th percentile speed is considerably lower than the state-wide limit caused by a natural reduction of speed when passing the intersection with U.S. 52 Bypass (see Figure 2).

Station A 2

The results of the studies at this station are presented in Table 11. There is a significantly lower speed at night than during the day. The appearance of the illuminated city ahead may involuntarily cause a reduction of speed. No significant effect of posting a 50 mile per hour speed limit sign was registered.

Station A 3

This station is the first one within the developed area and was

assigned a 40 mile per hour speed limit. Although this station was used as a control station where weekly surveys were conducted, no significant change was recorded due to sign condition. Non-local vehicles traveled noticeably faster than local vehicles; however, no difference was found between day and night. Between stations A 3 and A 4 there is a crosswalk used by school children at certain times during the day. A particular study at this crosswalk (31) disclosed that the vehicles significantly reduced their speed when children were present, but not otherwise. At station A 3 a specific speed limit sign, "SPEED LIMIT 25 MPH WHEN CHILDREN PRESENT" was placed. Speed studies at station A 3 recorded no change in traveled speed, probably due to the fact that the crosswalk is barely visible from the sign. But the lack of change in speed also indicates no respect for the sign by itself.

Station A 4

Non-local vehicles were still traveling significantly faster than local ones within the 40 mile per hour speed zone. A significant change in the mean speed because of posting the sign was recorded but surprisingly in the opposite direction. The mean speed was higher after than prior to the posting of a speed limit. A noticeable difference between day and night 85th percentile speed was also disclosed at this station.

Station A 5

After posting the 40 mile per hour speed limit the mean speed was significantly higher but not the 85th percentile speed. Non-local vehicles still traveled considerably faster than local ones.

Station A 6

Customarily, reduction of speed limits is posted by increments

of ten miles per hour. An exception was made at this station where a 35 mile per hour speed limit sign was posted, thus reducing the speed limit by only five miles per hour, in order to better coincide with the actual 85th percentile speed. No significant change in traveled speeds after the posting of the sign was revealed. At night, however, the 85th percentile speed was conspicuously lower than during daytime. Six months after the entire program of speed surveys were completed a check survey was conducted at this station and revealed a slight reduction, but still insignificant, of the traveled speed. The 35 mile per hour speed limit sign was then replaced by a 30 mile per hour speed limit sign, and the results are shown in Table 12. It is obvious from the figures, and a statistical analysis also verifies it, that the lowering of the speed limit from 35 miles per hour to 30 miles per hour did not have any effect whatsoever.

Station A 7

The location of this station immediately ahead of a sharp curve (see Figures 2 and 4) gives as a result a speed pattern with very little variation. Most vehicles brake before entering the curve thus reducing their speed in order to achieve comfortable riding through the curve. None of the factors exhibited any significant change because of posting a 30 mile per hour speed limit.

Stations A 11, A 14, A 16, A 17

Speed studies in the outbound direction were not originally planned but were added later. For this reason no data as to vehicle residence were available when no signs existed. The study in the outbound direction, essentially characterized as a check on directional

TABLE 12

OBSERVED RESULTS ON SPEED OF LOWERING A SPEED LIMIT

Passenger Vehicles	Speed Limit	
	35 mph	30 mph
Mean Speed	33.91	34.31
85th Percentile Speed	38.42	38.49
Speed Differential	9.09	8.47
10 mph Pace	28-37	30-39
Per Cent in Pace	74.6	78.9
Standard Deviation	4.70	4.26
Per Cent of Vehicles exceeding the speed limit by 5 mph or more	10.1	37.8

speed patterns, revealed a significantly lower speed at station A 16 after a 35 mile per hour speed limit had been established. For any other sign condition no noticeable change was recorded. An analysis of differences in directional speeds was regarded of little importance because a speed zone in one direction very seldom coincides with a similar zone in the other direction.

Location B

This location exhibited specific characteristics because of the absence of extensive development along the highway. For this reason it could not advantageously be compared with and analyzed together with

any other location. Although 65 miles per hour is permitted the 85th percentile speed was 55.9 miles per hour in the open area and 54.0 miles per hour at the "Speed Zone Ahead" sign during the day. A relatively sharp curve immediately beyond the 40 mile per hour speed limit sign reduced the 85th percentile speed to 30.5 miles per hour (63). The 50 mile per hour speed zone, about three miles long, revealed a natural reduction of the 85th percentile speed from 53.3 miles per hour at the beginning of the speed zone to 50.6 miles per hour at the end of the same zone. During the night, vehicles reduced their speed considerably more within the 50 mile per hour zone than during the day. The absence of illumination along the road, the darkness because of vegetation, and the non-existence of development may explain this phenomena. Furthermore, non-local vehicles also reduced their speed substantially more than local vehicles which obviously are more familiar with the road.

Locations C, D, and E

These three locations, each one displaying a predominant type of development, were statistically tested against each other in order to determine whether or not there is any significant difference in speed pattern by type of development. The result, disclosed in Table 11, revealed significant differences among most of the factors, including even significant interaction. This may indicate that certain combinations of development, sign condition, and other factors significantly change the speed pattern. The lack of comparability of the locations may explain the significant interactions. It was generally found that non-local vehicles at all locations and for all sign conditions traveled

noticeably faster than local vehicles. Night driving characteristics differed from day driving characteristics in many respects depending upon location and sign condition. Illumination of the highway together with alignment attributes may also have played a significant role.

CONCLUSIONS AND RECOMMENDATIONS

This study has revealed that drivers, in general, do not drive according to posted speed limit signs. Most of them select a speed which they consider proper, reasonable, and safe for conditions prevalent, regardless of regulations. Moreover, it is shown that when speed limits are determined from the 85th percentile speed, traveled speeds are not affected. The fear that the establishment of a speed limit which might appear relatively high will create a new speed pattern with faster speeds appears to have no foundation.

The study of the effect of roadside development on speed patterns did not produce conclusive results, but the many significant differences noted in the speed patterns indicate a possibility of an effect on speed pattern by type of development.

Some authors (85) have expressed doubts concerning the reliability of fixed-point speed measurements. Hourly, daily, and monthly variations of the speed pattern constitute an enigma which needs to be investigated more carefully. The classical method of using the number of observations as the sole criteria for determining the adequacy of a sample may give erroneous or misleading results. Even in this study unexplained variations in speed occurred under the very same sign conditions, keeping other factors presumedly as constant as possible. Selected locations at which speed studies could be conducted continuously would probably

increase the knowledge on seasonal variations of speed. Then, if necessary, correction factors could be developed which could be used to eliminate the bias that occurs because of hourly, daily, and monthly variation of speeds. It is recommended that such a study be initiated.

It is undoubtedly evident that the relationship between speed and roadside development is extremely complex. More detailed studies taking into account all of the factors, many of which were not tested in this study, will probably increase the knowledge and eventually develop additional warrants for establishing reasonable speed limits.

Most drivers will obey a posted speed limit if, and only if, the sign is properly posted and the numerical limit is reasonable. Such signing also permits a more efficient enforcement of speed limits, whereas enforcement of unreasonable speed limits efficiently requires a police force which no community can afford.

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APPENDIX A

NOTATION USED

A	Speed study location A
A 1	Speed measurement station 1 at location A
A 2	Speed measurement station 2 at location A
α	Level of significance
B	Speed study location B
β	Position angle of radar unit with road edge
C	Speed study location C
c	Speed limit sign condition
c 1	Sign condition 1 (see page 90)
c 2	Sign condition 2 (see page 90)
D	Speed study location D
d	Traffic flow direction
d 1	Inbound flow
d 2	Outbound flow
df	Degrees of freedom
E	Speed study location E
e	Error
F	Function of the F distribution
f	Frequency of vehicles for a specific speed
g	Number of replications for the same sign condition (cell)
H	Statistical hypothesis

i	Index of summation
j	Index of summation
k	Number of conditions (cells)
L	Location
MS	Mean square
MSe	Error mean square
m	Number of vehicles exceeding a posted speed limit by five miles per hour or more
N	Number of vehicles (volume) passing a speed measurement station
n	Number of vehicles, the speed of which is recorded, passing a speed measurement station ($n < N$)
R	Range
S	Effective range in feet of radar speed meter
SS	Sum of squares
SZA	Speed Zone Ahead
s	Standard deviation for a sample statistic
t	Time factor
t 1	Day
t 2	Night
u	Transformed fraction (see page 57)
V	Calculated speed from a frequency distribution
$\overline{V}$	Mean speed
V_{15}	15th percentile speed
V_{50}	50th percentile (median) speed
V_{85}	85th percentile speed
V_{diff}	Speed differential

v	Vehicle factor
v 1	Local vehicles
v 2	Non-local vehicles
w	Lane width, roadway width, in feet
X	Variable in a frequency distribution, e. g., the speed
x	Variable in a frequency distribution, e. g., the speed
y	Lateral distance in feet from radar unit to road edge
z	Fraction of vehicles exceeding a posted speed limit by five miles per hour or more (see also page 57)

DEFINITION OF STATISTICAL TERMS

General Definitions

Population	The total group of elements under investigation
Sample	A number of elements selected from the population
Normal Distribution	A certain theoretical relation between values of the measured variable and the relative frequency of the value
Population Statistic	A numerical characteristic of the population, e. g., the population mean
Sample Statistic	A numerical characteristic of the sample, e. g., the sample mean
Variance	A measure of the variability or dispersion of the values
Standard Deviation	Square root of the variance
Statistical Hypothesis	A statement delimiting the possible value that a population parameter may have

Definitions Related to Speed

Mean Speed	The average of individual speeds; $\overline{V} = \frac{\sum_{i=1}^{n} V_i}{n}$ where V_i is the individual speed measurement. For data arranged in a frequency distribution containing speed classes and frequencies within these classes $\overline{V} = \frac{\sum_{i=1}^{n} f_i V_i}{\sum_{i=1}^{n} f_i}$ where V_i now is the midvalue of class i and f_i the frequency of measurements in class i. By definition $n = \sum_{i=1}^{n} f_i$
pth Percentile Speed	That speed at and below which p per cent of the drivers travel
Median Speed	The 50th percentile speed
Speed Differential	The difference between the 85th percentile speed and the 15th percentile speed; $V_{diff} = V_{85} - V_{15}$
10 mph Pace	The speed increment of 10 miles per hour in which most of the drivers are included
Per Cent in Pace	Per cent of drivers within the pace limits

Range	The difference between the fastest and the slowest speed recorded for a particular condition; $R = V_{max} - V_{min}$
Variance	A measure of the variability or dispersion of the speed within a speed distribution, defined by $s^2 = \frac{\sum_{i=1}^{n} f_i (V_i - \bar{V})^2}{n - 1}$
Standard Deviation	Square root of the variance $S = \sqrt{\frac{\sum_{i=1}^{n} f_i (V_i - \bar{V})^2}{n - 1}}$
Mean Square	Sum of squares divided by degrees of freedom

SPEED LIMIT SIGN CONDITIONS

The following notation is consistently used to delineate the various sign conditions at location A. The signs were posted in the same order as the numbering outlines.

c 1	No speed limit sign posted at any station.
c 2	40 mile per hour speed limit signs posted, in inbound direction, north of station A 3 and A 5; in outbound direction, opposite station A 5.
c 3	Additional 40 mile per hour speed limit signs posted north of station A 4 in inbound direction; and at station A 14 in outbound direction.
c 4	35 mile per hour signs posted north of inbound station A 6 and at outbound station A 16.
c 5	30 mile per hour speed limit signs posted at inbound station A 7 and south of outbound station A 17.
c 6	50 mile per hour speed limit signs posted at inbound station A 2 and opposite this station for the outbound direction.
c 7	"Speed Zone Ahead" sign posted at inbound station A 1. "Speed Zone Ends" sign posted in outbound direction at the intersection with U.S. 52 Bypass.

c 8 Special signs with inscription "SPEED LIMIT 25 MPH WHEN CHILDREN PRESENT" posted at inbound station A 3 and outbound station A 14.

c 9 The 35 mile per hour sign north of inbound station A 6 replaced by a 30 mile per hour speed limit sign; the 30 mile per hour sign at station A 7 simultaneously removed.

For additional reference, see Figure 2.

At the other locations the numerical limit is used as a notation for the sign condition because the limits were established prior to the studies.

APPENDIX B

SUMMARY OF DATA

In order to keep this report within reasonable size publishing of the numerous speed distributions obtained is deliberately omitted. The most important data calculated for various conditions and factors are compiled in Table 13, which concerns speed parameters, and Table 14, which deals with speed violations. Notations used in those tables are defined in Appendix A.

TABLE 13

SUMMARY OF DATA: SPEED PARAMETERS

LOCATION STATION	FACTOR	SIGN COND.	N	n	MEAN SPEED	SPEED PERCENTILES			SPEED DIFF.	10 MPH PACE		STD. DEV.
						V_{15}	V_{50}	V_{85}		RANGE	PER CENT	
A 1	v 1	c 1	88	80	43.05	35.97	42.50	51.09	15.12	36-45	52.6	7.35
			78	70	43.81	35.64	43.27	52.27	16.63	40-49	50.0	7.41
			91	74	44.53	37.80	43.90	52.63	14.83	40-49	51.3	7.15
		c 7	67	60	42.27	33.98	41.50	50.84	16.86	34-43	46.6	7.66
	v 2	c 1	97	88	45.66	37.61	45.52	52.41	14.80	42-51	54.6	7.35
			111	90	43.25	33.66	42.58	50.78	17.12	38-47	55.6	7.69
			96	89	44.28	38.57	44.19	50.41	11.84	40-49	61.7	5.93
		c 7	104	95	43.24	36.53	42.68	50.47	13.94	36-45	58.8	6.41
	t 1	c 1	185	168	44.42	36.46	44.35	51.79	15.33	40-49	48.7	7.45
			189	160	43.50	35.53	42.86	51.15	15.62	38-47	50.2	7.57
			187	163	44.39	38.22	44.07	51.42	13.20	40-49	57.0	6.50
		c 7	171	155	42.86	35.84	42.06	50.57	14.73	36-45	53.1	6.95
	t 2	c 1	111	101	44.35	36.13	43.19	53.63	17.50	36-45	52.6	8.08
			162	143	38.63	30.93	38.85	45.28	14.35	36-45	55.9	6.72
		c 7	155	138	38.49	30.38	38.07	46.32	15.94	32-41	52.9	7.76

TABLE 13 (continued)

SUMMARY OF DATA: SPEED PARAMETERS

LOCATION STATION	FACTOR	SIGN COND.	N	n	MEAN SPEED	SPEED PERCENTILES			SPEED DIFF.	10 MPH PACE		STD. DEV.
						V_{15}	V_{50}	V_{85}		RANGE	PER CENT	
A 2	v 1	c 1	90	87	42.63	36.69	43.13	51.71	15.02	38-47	52.8	6.72
			72	60	42.77	36.68	42.49	49.19	12.51	38-47	56.7	5.84
			75	68	44.38	37.91	44.51	51.36	13.45	38-47	60.3	6.22
		c 6	89	77	44.42	37.65	43.59	50.93	13.28	36-45	58.5	6.27
		c 7	85	74	44.39	37.99	44.74	51.22	13.23	40-49	56.7	6.72
			73	59	42.57	35.83	42.50	49.97	14.14	36-45	60.9	5.96
			70	60	46.20	39.21	45.77	53.50	14.29	38-47	55.1	7.06
			87	72	47.22	39.41	47.77	55.57	16.16	42-51	54.1	6.90
	v 2	c 1	94	93	43.33	37.97	44.50	50.41	12.44	40-49	62.3	5.52
			109	96	45.36	39.55	44.87	52.31	12.76	40-49	60.4	6.13
			113	101	47.25	39.95	46.94	54.95	15.00	42-51	58.4	7.15
		c 6	114	92	44.98	38.34	44.96	50.78	12.44	38-47	57.5	6.35
		c 7	124	107	47.32	41.53	47.00	53.88	12.35	42-51	61.7	5.86
			134	112	45.04	39.97	44.84	50.62	10.65	42-51	66.9	5.46
			100	85	46.76	39.69	46.50	53.63	13.94	42-51	54.0	6.82
			137	112	47.87	41.97	46.50	53.86	11.89	44-53	60.7	5.46

TABLE 13 (continued)

SUMMARY OF DATA: SPEED PARAMETERS

LOCATION STATION	FACTOR	SIGN COND.	N	n	MEAN SPEED	SPEED PERCENTILES			SPEED DIFF.	10 MPH PACE		STD. DEV.
						V_{15}	V_{50}	V_{85}		RANGE	PER CENT	
A 2	t 1	c 1	184	180	43.99	37.29	44.01	50.95	13.66	40-49	56.2	6.13
			181	156	44.36	38.03	44.20	50.83	12.80	40-49	58.4	6.15
			188	169	46.10	38.93	45.99	53.70	14.77	42-51	57.4	6.92
		c 6	203	169	44.73	38.05	44.31	50.84	12.79	38-47	56.2	6.32
		c 7	209	181	46.12	40.10	46.07	53.14	13.04	42-51	58.7	6.40
			207	171	44.19	37.93	44.23	50.41	12.48	38-47	62.7	5.76
			170	145	46.78	39.47	46.26	53.56	14.09	40-49	53.2	6.92
			224	184	47.62	41.09	47.62	54.37	13.28	42-51	58.2	6.06
	t 2	c 1	200	195	42.69	35.75	43.55	51.00	15.25	38-47	52.9	7.36
			205	165	39.65	32.12	39.27	46.56	14.44	32-41	52.7	6.92
			244	208	41.79	34.46	40.77	49.98	15.52	34-43	55.8	7.31
		c 6	173	147	41.33	33.21	40.86	49.69	16.48	36-45	52.4	7.15
		c 7	156	138	40.80	34.63	40.50	46.54	11.91	36-45	61.7	5.91
			140	126	43.87	37.47	42.92	51.06	13.59	40-49	57.8	6.24
			110	97	44.15	36.89	43.99	50.75	13.86	40-49	54.7	4.26
			112	102	43.70	36.68	42.96	50.57	13.89	40-49	58.8	6.36

TABLE 13 (continued)

SUMMARY OF DATA: SPEED PARAMETERS

LOCATION STATION	FACTOR	SIGN COND.	N	n	MEAN SPEED	SPEED PERCENTILES			SPEED DIFF.	10 MPH PACE		STD. DEV.
						V_{15}	V_{50}	V_{85}		RANGE	PER CENT	
A 3	v 1	c 1	91	87	35.08	28.90	34.38	41.53	12.63	28-37	61.9	6.02
			123	110	34.06	29.00	33.64	39.94	10.94	28-37	73.8	4.88
		c 2	116	101	34.68	29.53	34.94	38.81	9.28	30-39	75.3	4.90
			109	85	35.23	30.98	34.91	39.61	8.63	30-39	79.9	4.36
			115	100	36.28	31.50	37.08	42.83	11.33	32-41	64.0	5.65
			95	80	35.65	30.85	35.62	40.67	9.82	30-39	73.9	4.89
			100	86	35.80	30.20	35.94	41.52	11.32	30-39	68.6	4.84
			110	103	36.15	30.83	35.27	41.76	10.93	30-39	66.1	5.31
		c 6	109	88	35.55	30.34	35.62	40.33	9.99	30-39	70.5	4.68
		c 7	88	78	34.55	29.67	34.62	38.72	9.05	30-39	74.4	4.68
			144	115	35.56	30.07	35.37	41.77	11.70	30-39	65.3	4.92
			107	87	34.15	29.15	34.59	39.68	10.53	30-39	67.9	4.86
			75	63	37.77	31.60	37.05	43.03	11.43	34-43	69.7	5.10
			107	84	36.17	30.35	36.17	42.11	11.76	34-43	64.2	5.54

TABLE 13 (continued)

SUMMARY OF DATA: SPEED PARAMETERS

LOCATION STATION	FACTOR	SIGN COND.	N	n	MEAN SPEED	SPEED PERCENTILES			SPEED DIFF.	10 MPH PACE		STD. DEV.
						V_{15}	V_{50}	V_{85}		RANGE	PER CENT	
A 3	v 2	c 1	65	64	37.63	32.37	37.50	43.33	10.96	32-41	65.6	5.08
			90	83	37.50	31.00	36.85	44.06	13.06	32-41	59.2	6.64
		c 2	100	84	37.62	31.90	37.95	43.35	11.45	32-41	63.1	5.34
			125	104	37.23	32.75	37.33	41.98	9.23	32-41	74.9	4.26
			96	82	37.11	32.73	37.00	41.08	8.35	32-41	78.1	4.33
			124	104	37.67	31.74	37.15	42.59	10.85	34-43	69.2	5.89
			119	102	36.54	31.97	36.83	42.83	10.86	32-41	71.6	5.65
			111	97	36.67	30.94	36.71	42.48	11.54	30-39	62.9	5.34
		c 6	127	98	37.42	32.85	37.08	41.41	8.56	32-41	75.6	5.08
		c 7	112	95	36.37	32.00	35.92	41.10	9.10	32-41	75.7	4.41
			111	98	36.77	31.40	36.67	42.06	10.66	34-43	72.5	4.97
			127	103	36.46	31.17	36.44	41.59	10.42	34-43	70.9	4.72
			110	98	38.46	32.08	38.28	44.79	12.71	32-41	60.3	6.08
			97	81	37.29	32.99	37.03	41.86	8.87	32-41	75.3	4.94

TABLE 13 (continued)

SUMMARY OF DATA: SPEED PARAMETERS

LOCATION STATION	FACTOR	SIGN COND.	N	n	MEAN SPEED	SPEED PERCENTILES			SPEED DIFF.	10 MPH PACE		STD. DEV.
						V_{15}	V_{50}	V_{85}		RANGE	PER CENT	
A 3	t 1	c 1	156	151	36.15	30.02	35.58	42.48	12.46	32-41	60.9	5.65
			213	193	35.54	29.58	34.89	41.40	11.82	28-37	64.3	5.28
		c 2	216	185	36.01	30.61	35.91	41.72	11.11	32-41	65.9	5.31
			234	189	36.33	31.63	36.02	41.10	9.37	30-39	74.6	4.41
			211	182	37.20	32.05	37.04	42.05	10.00	32-41	70.3	5.08
			219	184	36.79	31.22	36.50	41.90	10.68	32-41	67.8	5.56
			219	188	36.74	31.59	36.42	41.94	10.35	32-41	69.2	5.37
			221	200	36.40	30.38	36.07	42.30	11.47	30-39	64.5	5.33
		c 6	236	186	36.53	31.35	36.41	41.03	9.68	32-41	72.7	4.98
		c 7	200	173	35.55	30.97	35.35	40.37	9.40	30-39	72.9	4.62
			255	213	36.12	30.62	35.95	41.89	11.27	34-43	58.5	4.98
			234	190	35.41	30.09	35.52	40.66	10.57	32-41	66.9	4.92
			185	161	38.19	32.26	37.69	43.98	11.72	34-43	63.4	5.74
			204	165	36.72	31.74	36.69	41.98	10.24	32-41	69.1	5.28

TABLE 13 (continued)

SUMMARY OF DATA: SPEED PARAMETERS

LOCATION STATION	FACTOR	SIGN COND.	N	n	MEAN SPEED	SPEED PERCENTILES			SPEED DIFF.	10 MPH PACE		STD. DEV.
						V_{15}	V_{50}	V_{85}		RANGE	PER CENT	
A 3	t 2	c 1	129	124	36.53	29.22	35.50	42.97	13.75	32-41	59.6	6.64
			216	203	36.09	30.38	35.48	41.41	11.03	32-41	63.5	5.36
		c 2	210	168	35.49	30.51	34.79	40.85	10.34	30-39	68.4	5.04
			171	146	36.61	30.87	36.17	42.35	11.48	32-41	63.7	5.28
			159	133	36.24	30.30	35.33	41.50	11.20	32-41	64.6	6.00
			204	169	35.74	31.02	35.40	40.40	9.38	30-39	74.5	4.99
			164	146	36.69	30.65	36.54	43.15	12.50	32-41	60.3	5.62
			151	123	34.97	29.71	34.75	40.51	10.80	30-39	68.3	5.32
		c 6	238	195	35.61	30.24	35.14	41.75	11.51	30-39	65.7	5.34
		c 7	242	191	35.24	29.80	34.91	40.79	10.99	30-39	57.1	5.31
			173	146	34.76	29.13	34.36	40.70	11.57	30-39	63.7	5.42
			172	145	34.87	28.72	34.43	40.95	12.23	32-41	61.4	5.88
			148	126	37.86	31.50	36.98	42.52	11.02	32-41	64.3	5.50
			112	101	38.36	31.68	38.38	45.02	13.34	32-41	53.4	6.46

TABLE 13 (continued)

SUMMARY OF DATA: SPEED PARAMETERS

LOCATION STATION	FACTOR	SIGN COND.	N	n	MEAN SPEED	SPEED PERCENTILES			SPEED DIFF.	10 MPH PACE		STD. DEV.
						V_{15}	V_{50}	V_{85}		RANGE	PER CENT	
A 4	v 1	c 1	122	116	33.72	28.00	33.50	39.42	11.42	28-37	73.0	5.72
		c 2	138	107	36.56	31.50	36.18	40.77	9.27	32-41	74.8	4.59
		c 3	93	79	36.20	31.22	35.96	41.80	9.58	32-41	67.1	5.42
			111	92	36.43	31.13	36.35	41.32	10.19	30-39	71.7	4.86
			134	110	35.79	29.59	35.29	40.68	11.09	30-39	71.8	4.62
		c 7	139	109	35.86	30.29	35.34	41.58	11.29	32-41	52.4	5.19
	v 2	c 1	94	90	36.23	30.48	35.64	43.01	12.53	28-37	62.2	5.80
		c 2	85	76	37.92	33.92	38.01	43.67	9.75	32-41	75.0	4.83
		c 3	101	85	38.03	32.84	37.82	42.90	10.06	32-41	73.0	4.74
			125	110	37.86	32.52	37.50	43.98	11.46	32-41	70.1	5.64
			115	103	36.99	31.57	37.20	41.43	9.86	32-41	73.8	4.70
		c 7	138	117	37.61	31.63	37.35	42.99	11.36	32-41	71.7	4.96

TABLE 13 (continued)

SUMMARY OF DATA: SPEED PARAMETERS

LOCATION	FACTOR	SIGN	N	n	MEAN	SPEED PERCENTILES			SPEED	10 MPH PACE		STD.
STATION		COND.			SPEED	V_{15}	V_{50}	V_{85}	DIFF.	RANGE	PER CENT	DEV.
A 4	t 1	c 1	216	206	34.82	28.83	34.40	41.91	13.08	28-37	62.7	5.88
		c 2	223	183	37.30	32.59	36.85	41.39	8.80	32-41	75.0	4.78
		c 3	194	164	37.23	32.14	36.94	42.25	10.11	32-41	70.3	5.04
			236	202	37.21	31.84	36.99	42.64	10.80	32-41	69.3	5.34
			249	213	36.37	31.50	36.22	41.06	9.56	32-41	72.4	4.70
		c 7	277	226	36.77	31.50	36.67	42.05	10.55	32-41	67.7	5.08
	t 2	c 1	148	146	36.17	29.98	35.98	43.00	13.02	30-39	59.5	6.12
		c 2	197	169	37.14	30.91	36.94	43.03	12.12	32-41	62.7	5.94
		c 3	228	187	36.42	30.91	36.00	42.35	10.44	32-41	65.3	5.81
			149	129	37.28	31.78	37.05	42.51	10.73	32-41	66.0	5.29
		c 7	169	158	36.73	32.10	36.48	42.72	10.62	32-41	65.5	5.70

TABLE 13 (continued)

SUMMARY OF DATA: SPEED PARAMETERS

LOCATION STATION	FACTOR	SIGN COND.	N	n	MEAN SPEED	SPEED PERCENTILES			SPEED DIFF.	10 MPH PACE		STD. DEV.
						V_{15}	V_{50}	V_{85}		RANGE	PER CENT	
A 5	v 1	c 1	114	103	32.70	28.93	33.00	39.16	10.23	28-37	73.8	4.75
		c 2	173	147	35.51	30.85	35.25	40.12	9.27	30-39	74.8	4.59
		c 3	161	137	36.70	32.21	36.62	41.01	8.80	32-41	76.0	4.41
			126	104	36.63	32.65	36.28	40.72	8.07	32-41	81.7	3.95
		c 7	139	115	35.16	29.55	35.44	40.47	10.92	30-39	66.1	5.07
	v 2	c 1	83	79	35.96	32.63	36.05	41.84	9.21	32-41	77.2	4.84
		c 2	118	93	38.56	33.93	38.70	43.25	9.32	34-43	73.2	4.71
		c 3	136	118	38.92	34.13	38.72	44.16	10.03	34-43	71.2	4.44
			102	82	38.48	33.74	39.58	42.77	9.03	34-43	75.6	4.27
		c 7	105	85	36.97	32.54	36.77	41.05	8.51	32-41	79.9	4.31

TABLE 13 (continued)

SUMMARY OF DATA: SPEED PARAMETERS

LOCATION	FACTOR	SIGN	N	n	MEAN	SPEED PERCENTILES			SPEED	10 MPH PACE		STD.
STATION		COND.			SPEED	V_{15}	V_{50}	V_{85}	DIFF.	RANGE	PER CENT	DEV.
A 5	t 1	c 1	197	182	35.12	29.94	34.53	40.52	10.58	28-37	69.2	5.05
		c 2	291	240	36.69	31.71	36.46	41.50	9.79	32-41	71.3	4.88
		c 3	297	255	37.73	33.30	37.60	42.64	9.79	34-43	72.5	4.56
			228	186	37.45	33.04	37.07	41.77	8.73	32-41	78.0	4.20
		c 7	244	200	35.93	30.68	36.06	40.77	10.09	32-41	70.5	4.84
	t 2	c 1	211	195	33.75	29.52	34.37	40.45	10.93	30-39	66.2	5.04
		c 2	237	206	36.18	31.68	35.96	41.09	9.41	32-41	73.3	4.50
		c 3	239	195	35.65	29.60	35.67	40.57	10.97	30-39	70.3	4.75
		c 7	221	182	34.98	29.98	34.43	39.78	9.80	30-39	72.0	5.01

TABLE 13 (continued)

SUMMARY OF DATA: SPEED PARAMETERS

LOCATION STATION	FACTOR	SIGN COND.	N	n	MEAN SPEED	SPEED PERCENTILES			SPEED DIFF.	10 MPH PACE		STD. DEV.
						V_{15}	V_{50}	V_{85}		RANGE	PER CENT	
A 6	v 1	c 1	155	143	32.28	27.90	31.84	37.61	9.71	26-35	77.6	4.24
		c 3	175	129	33.03	28.62	33.06	37.28	8.66	28-37	77.6	4.00
		c 5	165	126	32.64	28.45	32.64	36.78	8.33	28-37	84.2	3.88
		c 6	202	143	32.36	27.99	31.98	37.23	9.24	28-37	74.1	4.44
		c 7	158	118	32.40	28.17	32.19	36.64	8.47	28-37	79.7	4.23
			146	116	33.64	29.62	33.66	38.20	8.58	28-37	78.6	4.28
			148	114	35.26	30.23	35.07	40.05	9.72	30-39	71.1	4.94
	v 2	c 1	122	116	31.64	26.60	31.11	37.17	10.57	28-37	68.2	5.08
		c 3	168	121	33.85	28.59	33.74	39.43	10.84	28-37	67.9	5.26
		c 5	116	93	33.68	28.78	32.93	38.97	10.19	28-37	74.1	5.31
		c 6	138	115	32.73	29.52	32.51	36.70	7.18	28-37	80.9	4.13
		c 7	117	92	32.96	28.44	32.66	38.05	9.61	30-39	71.7	4.98
			122	100	35.10	30.43	34.38	40.17	9.74	30-39	74.0	5.72
			118	103	35.36	31.41	35.37	39.44	8.03	30-39	81.5	3.68

TABLE 13 (continued)

SUMMARY OF DATA: SPEED PARAMETERS

LOCATION STATION	FACTOR	SIGN COND.	N	n	MEAN SPEED	SPEED PERCENTILES			SPEED DIFF.	10 MPH PACE		STD. DEV.
						V_{15}	V_{50}	V_{85}		RANGE	PER CENT	
A 6	t 1	c 1	277	259	31.99	27.61	31.53	37.38	9.77	26-35	73.0	4.65
		c 3	343	250	33.48	28.61	33.37	38.44	9.83	28-37	72.8	4.83
		c 5	281	219	33.08	28.58	32.75	37.34	8.76	28-37	79.8	4.58
		c 6	340	258	32.52	27.60	32.26	37.02	9.42	28-37	77.1	4.31
		c 7	275	210	32.64	28.25	32.41	37.26	9.01	28-37	76.1	5.58
			268	216	34.31	29.94	33.99	39.19	9.25	30-39	75.5	4.48
			266	217	35.30	30.77	35.23	39.76	8.99	30-39	76.1	4.38
	t 2	c 1	195	186	31.61	26.36	31.78	36.78	10.36	26-35	69.9	4.92
		c 3	231	175	31.72	26.53	31.32	36.84	10.31	28-37	69.7	4.98
		c 5	277	217	30.35	26.10	30.17	34.30	8.20	26-35	76.3	4.25
		c 6	280	211	30.79	26.61	30.59	34.84	8.23	26-35	78.6	4.12
		c 7	184	147	34.64	30.23	34.42	39.02	8.79	30-39	77.6	4.34
			143	119	33.24	29.37	33.21	37.42	8.05	28-37	80.8	4.68
			163	141	33.56	29.33	33.33	37.78	8.45	30-39	76.7	4.26

TABLE 13 (continued)

SUMMARY OF DATA: SPEED PARAMETERS

LOCATION STATION	FACTOR	SIGN COND.	N	n	MEAN SPEED	SPEED PERCENTILES			SPEED DIFF.	10 MPH PACE		STD. DEV.
						V_{15}	V_{50}	V_{85}		RANGE	PER CENT	
A 7	v 1	c 1	162	155	26.97	22.63	27.00	31.07	8.44	22-31	79.5	4.20
		c 2	183	145	28.42	24.44	28.02	32.54	8.10	24-33	82.1	3.78
		c 3	169	142	28.18	24.45	27.68	31.91	7.46	24-33	86.0	3.83
		c 4	188 152	144 119	28.10 28.20	24.62 23.60	27.71 27.93	31.46 32.04	6.84 8.44	24-33 24-33	83.9 87.5	3.69 3.55
		c 7	167	133	28.61	25.21	28.50	31.97	6.76	24-33	86.5	3.26
	v 2	c 1	86	80	27.77	23.85	27.98	31.00	7.15	22-31	83.8	3.92
		c 2	113	91	27.44	73.20	27.95	31.10	7.90	22-31	82.4	3.73
		c 3	127	100	27.70	24.24	27.03	31.79	7.55	24-33	83.0	3.63
		c 4	120 124	90 99	27.30 28.22	22.91 24.08	27.23 28.32	30.78 32.01	7.87 7.93	22-31 24-33	83.4 82.8	4.22 4.20
		c 7	172	129	28.67	25.01	28.69	32.26	7.25	24-33	88.3	3.24

TABLE 13 (continued)

SUMMARY OF DATA: SPEED PARAMETERS

LOCATION STATION	FACTOR	SIGN COND.	N	n	MEAN SPEED	SPEED PERCENTILES			SPEED DIFF.	10 MPH PACE		STD. DEV.
						V_{15}	V_{50}	V_{85}		RANGE	PER CENT	
A 7	t 1	c 1	248	235	27.24	22.91	27.42	31.06	8.15	22-31	80.8	4.12
		c 2	296	236	28.04	24.06	27.96	31.76	7.70	24-33	81.0	3.79
		c 3	296	242	27.98	24.36	27.34	31.86	7.50	24-33	84.8	3.76
		c 4	308	234	27.79	24.08	27.54	31.27	7.19	22-31	82.5	3.91
			276	218	28.21	24.32	28.13	32.03	7.71	24-33	85.3	3.86
		c 7	339	262	28.64	25.09	28.59	32.12	6.88	24-33	87.4	3.26
	t 2	c 1	214	201	28.08	23.23	28.06	33.23	10.00	24-33	70.1	4.56
		c 2	273	220	26.82	22.19	26.67	31.15	8.96	22-31	76.7	4.42
		c 3	267	220	27.37	23.19	27.19	31.84	8.65	22-31	76.3	4.08
		c 4	235	201	27.52	22.91	27.24	32.22	9.31	24-33	73.5	4.32
		c 7	189	170	29.56	24.99	29.32	33.59	8.40	24-33	75.8	4.62

TABLE 13 (continued)

SUMMARY OF DATA: SPEED PARAMETERS

LOCATION STATION	FACTOR	SIGN COND.	N	n	MEAN SPEED	SPEED PERCENTILES			SPEED DIFF.	10 MPH PACE		STD. DEV.
						V_{15}	V_{50}	V_{85}		RANGE	PER CENT	
A 11	v 1	c 5	62	55	43.59	36.43	43.08	51.35	14.92	36-45	54.5	6.48
		c 6	48	45	45.21	39.81	44.88	49.77	9.96	40-49	71.1	6.04
			79	67	44.14	38.31	44.50	49.05	10.74	40-49	68.6	5.59
	v 2	c 5	72	56	44.14	37.97	42.40	51.37	13.40	36-45	64.2	7.25
		c 6	80	68	45.20	39.99	44.58	51.43	11.44	40-49	66.2	5.72
			86	73	43.05	36.99	42.79	49.78	12.79	38-47	57.5	6.19
	t 1	c 1	103	85	44.72	37.64	44.21	53.59	15.95	38-47	54.1	6.96
		c 5	134	111	43.87	37.03	42.69	51.35	14.32	36-45	59.5	6.88
		c 6	128	113	45.21	39.93	44.69	51.02	11.09	40-49	68.0	5.86
			165	141	43.57	37.64	44.07	49.38	11.74	40-49	61.4	5.94

TABLE 13 (continued)

SUMMARY OF DATA: SPEED PARAMETERS

LOCATION STATION	FACTOR	SIGN COND.	N	n	MEAN SPEED	SPEED PERCENTILES			SPEED DIFF.	10 MPH PACE		STD. DEV.
						V_{15}	V_{50}	V_{85}		RANGE	PER CENT	
A 14	v 1	c 2	145	113	37.30	33.50	37.17	41.66	8.16	34-43	80.6	3.89
			127	102	37.26	32.63	37.59	42.09	9.46	32-41	74.6	4.39
		c 3	94	84	38.36	33.59	38.13	42.72	9.13	34-43	75.0	4.73
		c 4	93	77	38.86	34.43	38.26	43.32	8.89	34-43	79.2	4.61
			115	96	38.06	32.98	38.27	43.37	10.39	32-41	71.8	5.43
			93	81	37.02	31.51	37.31	41.97	10.46	34-43	74.2	5.09
	v 2	c 2	136	121	39.49	34.88	39.83	44.03	9.15	36-45	74.8	4.72
			86	73	38.75	33.50	39.56	43.94	10.44	32-41	69.8	4.88
		c 3	75	68	38.29	33.18	38.35	43.43	10.25	34-43	69.1	4.65
		c 4	85	71	39.26	34.07	39.39	44.45	10.38	36-45	69.1	5.19
			130	104	39.17	34.81	38.91	43.17	8.36	36-45	78.7	4.90
			94	80	38.75	34.27	38.50	43.15	8.88	34-43	77.6	4.98

TABLE 13 (continued)

SUMMARY OF DATA: SPEED PARAMETERS

LOCATION STATION	FACTOR	SIGN COND.	N	n	MEAN SPEED	SPEED PERCENTILES			SPEED DIFF.	10 MPH PACE		STD. DEV.
						V_{15}	V_{50}	V_{85}		RANGE	PER CENT	
A 14	t 1	c 1	93	75	37.19	32.31	35.89	42.95	10.64	32-41	69.3	5.59
		c 2	281	234	38.43	33.89	38.49	42.89	9.00	34-43	76.5	4.52
			213	175	38.07	32.97	38.31	42.86	9.79	32-41	72.6	4.66
		c 3	169	152	38.33	33.44	38.24	43.02	9.58	34-43	72.2	4.70
		c 4	178	148	39.05	34.32	38.74	43.93	9.61	34-43	73.6	4.89
			245	200	38.64	33.78	38.65	43.21	9.43	34-43	73.5	5.19
			187	161	37.88	33.32	37.93	42.36	9.04	34-43	75.9	5.11
A 16	v 1	c 4	167	116	33.42	29.40	33.26	37.28	7.88	28-37	81.1	3.90
		c 5	156	111	33.92	29.21	33.35	38.08	8.87	28-37	80.2	4.78
			170	115	32.78	28.10	32.36	37.31	9.21	28-37	73.9	4.96
			178	126	33.28	29.25	32.91	36.94	7.69	28-37	84.0	4.31
	v 2	c 4	145	106	33.88	30.08	33.88	37.50	7.42	30-39	84.1	4.05
		c 5	85	64	33.72	29.69	33.05	37.40	7.71	28-37	82.9	4.29
			89	63	33.68	28.74	34.00	37.79	9.05	28-37	73.0	4.64
			121	92	33.22	29.20	33.51	36.92	7.72	28-37	81.5	3.81

TABLE 13 (continued)

SUMMARY OF DATA: SPEED PARAMETERS

LOCATION STATION	FACTOR	SIGN COND.	N	n	MEAN SPEED	SPEED PERCENTILES			SPEED DIFF.	10 MPH PACE		STD. DEV.
						V_{15}	V_{50}	V_{85}		RANGE	PER CENT	
A 16	t 1	c 1	119	80	35.70	29.51	35.74	42.36	11.85	30-39	55.0	6.47
		c 4	312	222	33.66	29.75	33.58	37.37	7.62	30-39	81.7	3.97
		c 5	241	175	33.85	29.42	33.24	37.82	8.40	28-37	81.1	4.61
			259	178	33.10	28.26	32.76	37.45	9.19	28-37	73.6	4.86
			299	218	33.25	29.22	33.16	36.92	7.70	28-37	83.0	4.11
A 17	v 1	c 1	138	106	33.50	28.56	33.61	37.85	9.29	28-37	77.5	4.40
		c 4	133	97	32.00	27.42	31.78	36.71	9.29	26-35	76.3	4.29
			138	97	32.30	28.41	32.37	36.09	7.68	26-35	59.4	3.79
			106	78	31.60	26.72	30.76	37.19	10.47	26-35	74.3	4.89
			135	93	32.78	28.68	32.77	36.88	8.20	30-39	80.8	4.02
	v 2	c 1	97	75	33.57	28.40	33.68	38.86	10.46	30-39	69.3	5.96
		c 4	97	82	32.79	28.09	32.78	37.10	9.01	28-37	76.9	4.35
			86	66	32.74	29.13	32.76	36.26	7.13	28-37	84.9	3.38
			103	80	31.00	26.09	30.37	36.50	10.41	26-35	71.2	5.31
			103	82	33.18	29.34	32.81	37.23	7.89	28-37	80.4	4.22

TABLE 13 (continued)

SUMMARY OF DATA: SPEED PARAMETERS

LOCATION	FACTOR	SIGN	N	n	MEAN	SPEED PERCENTILES			SPEED	10 MPH PACE		STD.
STATION		COND.			SPEED	V_{15}	V_{50}	V_{85}	DIFF.	RANGE	PER CENT	DEV.
A 17	t 1	c 1	104	89	30.82	26.49	30.42	35.64	9.15	26-35	75.4	4.44
			235	181	33.53	27.60	33.64	38.39	10.79	28-37	73.0	4.64
		c 4	230	179	32.37	27.73	32.22	36.94	9.21	28-37	74.9	4.33
			224	163	32.48	28.78	32.55	36.23	7.45	28-37	80.9	3.67
			209	158	31.30	26.43	30.59	36.83	10.40	26-35	72.8	5.15
			238	175	32.97	29.07	32.79	37.06	7.99	28-37	78.2	4.12
B	v 1	65	30	23	46.24	36.97	47.02	52.53	15.56	44-53	61.2	7.82
		SZA	32	25	48.18	39.25	47.00	59.75	20.50	44-53	56.0	7.94
		50	38	32	45.88	40.03	45.75	51.63	11.60	44-53	71.9	6.56
		50	56	40	41.80	32.50	40.50	52.83	10.33	34-43	65.0	9.04
		40	50	39	35.32	31.76	35.60	39.56	7.80	32-41	84.8	3.82

TABLE 13 (continued)

SUMMARY OF DATA: SPEED PARAMETERS

LOCATION STATION	FACTOR	SIGN COND.	N	n	MEAN SPEED	SPEED PERCENTILES			SPEED DIFF.	10 MPH PACE		STD. DEV.
						V_{15}	V_{50}	V_{85}		RANGE	PER CENT	
B	v 2	65	56	46	50.11	43.85	49.82	58.57	14.72	44-53	58.7	7.10
		SZA	57	47	46.20	40.84	45.39	53.41	12.57	42-51	63.8	6.42
		50	64	52	47.42	41.29	47.26	54.24	12.95	42-51	57.6	6.22
		50	69	45	43.21	37.67	43.88	49.61	11.94	38-47	64.5	5.66
		40	110	68	34.53	30.14	34.12	39.44	9.30	30-39	75.0	4.34
	t 1	65	71	69	48.82	40.95	49.14	55.93	14.98	44-53	59.5	7.56
		SZA	89	72	46.89	40.22	46.17	53.99	13.77	40-49	54.1	7.08
		50	102	84	46.83	39.60	46.50	53.33	13.73	44-53	60.7	6.40
		50	125	85	42.55	34.76	42.11	50.61	15.85	38-47	50.7	7.48
		40	160	107	34.82	30.41	34.65	39.50	9.09	30-39	74.7	4.18

TABLE 13 (continued)

SUMMARY OF DATA: SPEED PARAMETERS

LOCATION STATION	FACTOR	SIGN COND.	N	n	MEAN SPEED	SPEED PERCENTILES			SPEED DIFF.	10 MPH PACE		STD. DEV.
						V_{15}	V_{50}	V_{85}		RANGE	PER CENT	
B	t 2	65	71	66	44.17	35.81	43.01	52.55	16.74	36-45	48.5	8.02
		SZA	80	70	47.61	40.48	47.70	54.50	14.02	46-55	54.2	7.16
		50	64	56	46.86	39.97	45.75	55.88	15.91	35-47	55.3	7.46
		50	135	100	39.42	31.50	39.13	45.83	14.33	34-43	58.6	7.08
		40	128	95	35.85	31.56	35.79	39.86	8.30	32-41	78.9	4.50
C	v 1	65	64	50	50.22	42.25	50.30	59.17	16.92	46-55	46.0	7.37
		40	75	59	39.45	33.78	39.20	45.68	11.90	34-43	66.0	5.62
		30	109	88	29.54	24.86	29.36	33.68	8.82	24-33	76.2	4.54
	v 2	65	73	44	54.64	45.21	56.49	62.47	17.26	54-63	47.7	8.11
		40	54	35	43.19	36.76	43.01	51.00	14.24	38-47	54.3	6.83
		30	86	66	30.44	25.20	30.51	34.95	9.75	26-35	71.3	4.98

TABLE 13 (continued)

SUMMARY OF DATA: SPEED PARAMETERS

LOCATION STATION	FACTOR	SIGN COND.	N	n	MEAN SPEED	SPEED PERCENTILES			SPEED DIFF.	10 MPH PACE		STD. DEV.
						V_{15}	V_{50}	V_{85}		RANGE	PER CENT	
C	t 1	65	137	94	52.69	43.50	52.25	60.79	17.29	50-59	41.6	8.04
		40	129	94	40.84	34.25	40.40	48.67	14.42	36-45	57.6	6.36
		30	195	154	29.93	25.00	29.78	34.24	9.24	24-33	74.2	4.75
	t 2	65	126	99	47.75	37.40	48.46	55.40	18.00	46-55	44.5	9.68
		40	137	101	42.66	35.24	42.42	50.45	15.21	36-45	55.4	6.72
		30	171	89	28.90	24.02	28.36	34.14	10.12	22-31	69.6	4.64
D	v 1	65	143 90	89 68	48.00 47.82	42.66 40.86	47.98 47.48	53.91 55.73	11.25 14.87	44-53 44-53	67.4 58.6	5.82 6.37
		SZA	84 104	53 82	48.52 46.99	40.62 41.28	48.00 46.11	54.86 53.37	14.24 12.09	44-53 42-51	52.7 63.5	7.60 6.27
		40	129 98	83 76	42.23 44.10	35.51 36.77	41.54 43.16	48.25 50.52	12.74 13.75	36-45 36-45	59.1 55.3	5.75 6.86
		30	148 154	102 121	33.75 34.81	28.65 29.35	33.23 34.61	38.34 40.05	9.69 10.70	30-39 30-39	74.5 67.0	5.39 4.88

TABLE 13 (continued)

SUMMARY OF DATA: SPEED PARAMETERS

LOCATION STATION	FACTOR	SIGN COND.	N	n	MEAN SPEED	SPEED PERCENTILES			SPEED DIFF.	10 MPH PACE		STD. DEV.
						V_{15}	V_{50}	V_{85}		RANGE	PER CENT	
D	v 2	65	135	61	51.03	44.72	50.65	60.03	15.31	46-55	57.5	7.53
			109	63	53.10	45.98	53.01	60.52	14.54	52-61	54.0	6.19
		SZA	88	46	48.48	42.05	49.48	55.56	13.51	42-51	54.3	6.51
			92	61	47.35	41.08	46.52	54.60	13.52	42-51	55.6	6.59
		40	95	56	46.25	38.43	46.01	54.32	15.89	42-51	48.2	7.26
			103	68	44.03	36.57	44.38	50.79	14.22	42-51	52.9	6.50
		30	107	60	35.90	30.17	35.29	41.32	11.15	30-39	60.0	5.00
			88	62	35.60	30.57	35.30	40.39	9.82	30-39	74.3	4.90
	t 1	65	278	150	49.15	43.08	49.69	56.27	13.19	44-53	61.8	6.62
			199	131	50.36	43.81	50.03	57.69	13.88	44-53	54.2	6.81
		SZA	172	99	48.50	40.96	48.57	55.14	14.18	44-53	51.6	7.12
			196	143	47.14	41.20	46.24	54.10	12.90	42-51	60.1	6.41
		40	224	139	43.85	36.08	43.56	51.32	15.24	40-49	51.8	6.80
			201	144	44.07	36.69	43.75	50.69	14.00	42-51	52.7	6.68
		30	255	162	34.55	29.40	34.01	39.58	10.18	30-39	69.2	5.34
			242	183	35.08	29.86	34.83	40.17	10.31	30-39	69.5	4.89

TABLE 13 (continued)

SUMMARY OF DATA: SPEED PARAMETERS

LOCATION STATION	FACTOR	SIGN COND.	N	n	MEAN SPEED	SPEED PERCENTILES			SPEED DIFF.	10 MPH PACE		STD. DEV.
						V_{15}	V_{50}	V_{85}		RANGE	PER CENT	
D	t 2	65	207	129	42.78	35.36	42.97	49.27	13.91	38-47	58.1	6.31
		SZA	231	157	39.44	34.23	39.33	45.06	10.83	34-43	64.4	6.07
		40	242	147	39.48	34.24	39.46	44.64	10.40	34-43	69.4	5.05
		30	248	192	31.83	27.31	29.65	36.67	9.36	28-37	73.4	4.84
E	v 1	SZA	101	59	44.09	38.59	43.41	50.42	11.83	38-47	67.8	5.74
			124	64	42.03	36.31	41.19	47.84	11.53	38-47	65.5	6.46
		40	105	56	41.47	36.25	40.78	47.09	10.84	36-45	71.4	4.94
			126	90	40.57	33.38	39.49	46.76	13.38	36-45	58.9	6.20
		30	154	72	28.17	23.60	27.63	32.41	8.81	24-33	81.9	3.70
			129	75	28.77	24.54	28.10	33.05	8.51	24-33	82.7	4.16

TABLE 13 (continued)

SUMMARY OF DATA: SPEED PARAMETERS

LOCATION STATION	FACTOR	SIGN COND.	N	n	MEAN SPEED	SPEED PERCENTILES			SPEED DIFF.	10 MPH PACE		STD. DEV.
						V_{15}	V_{50}	V_{85}		RANGE	PER CENT	
E	v 2	SZA	110	57	47.45	39.84	47.07	54.99	15.15	42-51	54.2	7.37
			141	81	42.94	36.20	43.19	49.81	13.61	42-51	58.1	5.79
		40	130	73	42.61	38.15	41.88	48.23	10.08	38-47	72.5	4.87
			138	71	40.78	35.64	40.63	46.28	10.64	34-43	71.9	4.82
		30	127	59	28.33	24.27	28.69	31.57	7.30	24-33	84.7	3.49
			130	72	28.47	24.19	28.22	33.56	9.37	22-31	76.3	4.12
	t 1	SZA	211	116	45.74	39.02	45.10	52.04	13.02	38-47	56.9	6.80
			265	145	42.54	36.23	42.09	49.34	13.11	36-45	60.0	6.11
		40	235	129	42.11	37.22	41.39	47.72	10.50	36-45	70.5	4.92
			264	161	40.66	34.70	40.35	46.54	11.84	36-45	62.8	5.64
		30	281	131	28.24	24.36	28.20	31.05	6.69	24-33	83.2	3.62
			259	147	28.62	24.38	28.15	32.19	7.81	24-33	79.0	4.14
	t 2	SZA	155	119	44.48	35.60	44.50	51.55	15.95	42-51	49.6	7.30
		40	225	149	39.00	32.63	37.93	45.70	13.07	32-41	57.8	6.20
		30	273	161	29.84	25.65	29.35	34.66	9.01	26-35	76.5	4.33

TABLE 14

SUMMARY OF DATA: SPEED VIOLATIONS

Location Station	Factor	Sign Cond.	m	n	z	u
A 1	v 1	c 1	0	80	.00000	.0000
			0	70	.00000	.0000
			0	74	.00000	.0000
		c 7	0	60	.00000	.0000
	v 2	c 1	0	88	.00000	.0000
			0	90	.00000	.0000
			0	89	.00000	.0000
		c 7	0	95	.00000	.0000
	t 1	c 1	0	168	.00000	.0000
			0	160	.00000	.0000
			0	163	.00000	.0000
		c 7	0	155	.00000	.0000
	t 2	c 1	0	101	.00000	.0000
			0	143	.00000	.0000
		c 7	0	138	.00000	.0000
A 2	v 1	c 1	1	87	.01149	.2148
			0	60	.00000	.0000
			3	68	.04412	.4232
		c 6	5	77	.06494	.5152
		c 7	3	74	.04054	.4054
			1	59	.01695	.2612
			4	60	.06667	.5224
			11	72	.15278	.8030

TABLE 14 (continued)

SUMMARY OF DATA: SPEED VIOLATIONS

Location Station	Factor	Sign Cond.	m	n	z	u
A 2	v 2	c 1	1	93	.01075	.2078
			5	96	.05208	.4604
			14	101	.13861	.7632
		c 6	6	92	.06522	.5166
		c 7	8	107	.07477	.5538
			4	112	.03571	.3806
			8	95	.08421	.5888
			11	112	.09821	.6376
	t 1	c 1	2	180	.01111	.2112
			5	186	.03205	.3600
			17	169	.10059	.6456
		c 6	11	169	.06509	.5160
		c 7	11	181	.06077	.4982
			5	171	.02924	.3436
			12	145	.08276	.5836
			22	184	.11957	.7060
	t 2	c 1	14	195	.07179	.5424
			4	165	.02424	.3126
			9	208	.04327	.4190
		c 6	5	147	.03401	.3910
		c 7	3	138	.02174	.2960
			4	126	.03175	.3584
			4	97	.04124	.4090
			3	102	.02941	.3446

TABLE 14 (continued)

SUMMARY OF DATA: SPEED VIOLATIONS

Location Station	Factor	Sign Cond.	m	n	z	u
A 3	v 1	c 1	3	87	.03448	.3736
			2	110	.01818	.2704
		c 2	1	101	.00990	.1994
			1	85	.01176	.2172
			8	100	.08000	.5734
			3	80	.03750	.3896
			2	86	.02326	.3062
			5	103	.04854	.4442
		c 6	2	88	.02273	.3026
		c 7	1	78	.01282	.2268
			1	115	.00870	.1870
			0	87	.00000	.0000
			5	63	.07937	.5712
			4	84	.04762	.4400
	v 2	c 1	3	64	.04688	.4374
			6	83	.07229	.5340
		c 2	4	84	.04762	.4400
			3	104	.02885	.3414
			2	82	.02439	.3134
			7	104	.06731	.5260
			10	102	.09804	.6370
			1	97	.01031	.2034
		c 6	3	98	.03061	.3518
		c 7	4	95	.04211	.4134
			2	98	.02041	.2866
			3	103	.02913	.3432
			13	98	.13265	.7456
			6	81	.07407	.5512

TABLE 14 (continued)

SUMMARY OF DATA: SPEED VIOLATIONS

Location Station	Factor	Sign Cond.	m	n	z	u
A 3	t 1	c 1	6	151	.03974	.4014
			8	193	.04145	.4154
		c 2	5	185	.02703	.3306
			4	189	.02116	.2922
			10	182	.05495	.4732
			10	184	.05435	.4706
			12	188	.06383	.5108
			6	200	.03000	.3482
		c 6	5	186	.02688	.3292
		c 7	5	173	.02890	.3416
			3	213	.01408	.2380
			3	190	.01579	.2518
			18	161	.11180	.6820
			10	165	.06060	.4976
	t 2	c 1	14	124	.11290	.6854
			8	203	.03941	.3996
		c 2	5	168	.02762	.3340
			9	146	.06164	.5018
			9	133	.06767	.5262
			5	169	.02959	.3460
			8	146	.05479	.4724
			5	123	.04065	.4060
		c 6	7	195	.03590	.3814
		c 7	7	191	.03665	.3852
			5	146	.03425	.3724
			8	145	.05517	.4740
			7	126	.05556	.4758
			12	101	.11881	.7036

TABLE 14 (continued)

SUMMARY OF DATA: SPEED VIOLATIONS

Location Station	Factor	Sign Cond.	m	n	z	u
A 4	v 1	c 1	4	116	.03448	.3734
		c 2	4	107	.03738	.3890
		c 3	3	79	.03797	.3922
			3	92	.03261	.3632
			1	110	.00909	.1910
		c 7	2	109	.01835	.2718
	v 2	c 1	8	90	.08889	.6054
		c 2	5	76	.06579	.5188
		c 3	4	85	.04706	.4372
			12	110	.10909	.6728
			4	103	.03883	.3966
		c 7	9	117	.07692	.5620
	t 1	c 1	12	206	.05825	.4874
		c 2	9	183	.04918	.4472
		c 3	7	164	.04268	.4162
			15	202	.07426	.5520
			5	213	.02347	.3074
		c 7	11	226	.04867	.4448

TABLE 14 (continued)

SUMMARY OF DATA: SPEED VIOLATIONS

Location Station	Factor	Sign Cond.	m	n	z	u
A 4	t 2	c 1	9	146	.06164	.5018
		c 2	13	169	.07692	.5620
		c 3	9	187	.04813	.4424
			8	128	.06202	.5032
		c 7	9	158	.05696	.4820
A 5	v 1	c 1	2	103	.01942	.2796
		c 2	2	147	.01361	.2340
		c 3	4	137	.02920	.3434
			2	104	.01923	.2782
		c 7	3	115	.02609	.3244
	v 2	c 1	3	79	.03797	.3922
		c 2	7	93	.07527	.5558
		c 3	11	118	.09322	.6208
			2	82	.02439	.3134
		c 7	3	85	.03529	.3778
	t 1	c 1	5	182	.02747	.3330
		c 2	9	240	.03750	.3896
		c 3	15	255	.05882	.4898
			4	186	.02151	.2944
		c 7	6	200	.03000	.3482

TABLE 14 (continued)

SUMMARY OF DATA: SPEED VIOLATIONS

Location Station	Factor	Sign Cond.	m	n	z	u
A 5	t 2	c 1	4	195	.02051	.2876
		c 2	6	206	.02913	.3428
		c 3	6	195	.03077	.3526
		c 7	4	182	.02198	.2976
A 6	v 1	c 1	2	143	.01399	.2372
		c 3	4	129	.03101	.3542
		c 5	1	126	.00794	.1784
		c 6	1	143	.00699	.1674
		c 7	1	118	.00847	.1844
			3	116	.02586	.3230
			7	114	.06140	.5008
	v 2	c 1	4	116	.03448	.3736
		c 3	10	121	.08264	.5830
		c 5	6	93	.06452	.5136
		c 6	2	115	.01739	.2646
		c 7	3	92	.03261	.3632
			9	100	.09000	.6094
			4	103	.03883	.3966

TABLE 14 (continued)

SUMMARY OF DATA: SPEED VIOLATIONS

Location Station	Factor	Sign Cond.	m	n	z	u
A 6	t 1	c 1	6	259	.02317	.3056
		c 3	14	250	.05600	.4778
		c 5	7	219	.03196	.3596
		c 6	3	258	.01163	.2160
		c 7	4	210	.01905	.2768
			12	216	.05556	.4758
			11	217	.05069	.4540
	t 2	c 1	4	186	.02151	.2944
		c 3	5	175	.02857	.3396
		c 5	3	217	.01382	.2358
		c 6	2	211	.00948	.1954
		c 7	10	147	.06803	.5280
			8	119	.06723	.5246
			6	141	.04255	.4156
A 7	v 1	c 1	3	155	.01935	.2790
		c 2	7	145	.04828	.4430
		c 3	5	142	.03521	.3774
		c 4	6	144	.04167	.4106
			2	119	.01681	.2602
		c 7	3	133	.02256	.3016

TABLE 14 (continued)

SUMMARY OF DATA: SPEED VIOLATIONS

Location Station	Factor	Sign Cond.	m	n	z	u
A 7	v 2	c 1	3	80	.03750	.3896
		c 2	1	91	.01099	.2100
		c 3	1	100	.01000	.2004
		c 4	5	90	.05556	.4758
			5	99	.05051	.4532
		c 7	1	129	.00775	.1764
	t 1	c 1	6	235	.02553	.3208
		c 2	8	236	.03390	.3704
		c 3	6	242	.02479	.3162
		c 4	11	234	.04701	.4370
			7	218	.03211	.3604
		c 7	4	262	.01527	.2478
	t 2	c 1	9	201	.04478	.4264
		c 2	5	220	.02273	.3026
		c 3	5	220	.02273	.3026
		c 4	8	201	.03980	.4016
		c 7	15	170	.08824	.6030

TABLE 14 (continued)

SUMMARY OF DATA: SPEED VIOLATIONS

Location Station	Factor	Sign Cond.	m	n	z	u
A 11	t 1	c 1	5	85	.05892	.4902
		c 5	8	111	.07207	.5434
		c 6	5	113	.04425	.4240
			5	141	.03546	.3788
A 14	t 1	c 1	7	75	.09333	.6210
		c 2	11	234	.04701	.4370
			8	175	.04571	.4310
		c 3	11	152	.07237	.5448
		c 4	12	148	.08108	.5774
			18	200	.09000	.6094
			8	161	.04969	.4496
A 16	t 1	c 1	15	80	.18750	.8956
		c 4	7	222	.03153	.3570
		c 5	13	175	.07429	.5520
			7	178	.03933	.3992
			8	218	.03670	.3856
A 17	t 1	c 1	14	89	.15730	.8156
			56	181	.30939	1.1796
		c 4	42	179	.23464	1.0114
			29	163	.17791	.8714
			29	158	.18354	.8854
			41	175	.23429	1.0104

TABLE 14 (continued

SUMMARY OF DATA: SPEED VIOLATIONS

Location Station	Factor	Sign Cond.	m	n	z	u
B	v 1	65	0	23	.00000	.0000
		SZA	0	25	.00000	.0000
		50	2	32	.06250	.5054
		50	3	40	.07500	.5550
		40	0	39	.00000	.0000
	v 2	65	0	46	.00000	.0000
		SZA	0	47	.00000	.0000
		50	4	52	.07692	.5620
		50	1	45	.02222	.2994
		40	0	68	.00000	.0000
	t 1	65	0	69	.00000	.0000
		SZA	0	72	.00000	.0000
		50	6	84	.07143	.5412
		50	4	85	.04706	.4376
		40	0	107	.00000	.0000

TABLE 14 (continued)

SUMMARY OF DATA: SPEED VIOLATIONS

Location Station	Factor	Sign Cond.	m	n	z	u
B	t 2	65	0	66	.00000	.0000
		SZA	0	70	.00000	.0000
		50	9	56	.16071	.8248
		50	2	100	.02000	.2838
		40	1	95	.01053	.2056
C	v 1	65	0	50	.00000	.0000
		40	9	59	.15254	.8024
		30	6	88	.06818	.5284
	v 2	65	2	44	.04545	.4296
		40	13	35	.37143	1.3108
		30	8	66	.12121	.7112
	t 1	65	2	94	.02128	.2928
		40	22	94	.23404	1.0098
		30	14	154	.09091	.6126
	t 2	65	2	99	.02020	.2816
		40	29	101	.28713	1.1312
		30	10	89	.11236	.6838

TABLE 14 (continued)

SUMMARY OF DATA: SPEED VIOLATIONS

Location Station	Factor	Sign Cond.	m	n	z	u
D	v 1	65	0	89	.00000	.0000
			0	68	.00000	.0000
		SZA	0	53	.00000	.0000
			0	82	.00000	.0000
		40	22	83	.26506	1.0818
			29	76	.38158	1.3318
		30	35	102	.34314	1.2516
			52	121	.42975	1.4298
	v 2	65	1	61	.01639	.2568
			0	63	.00000	.0000
		SZA	0	46	.00000	.0000
			0	61	.00000	.0000
		40	29	56	.51786	1.6064
			29	68	.42647	1.4234
		30	29	60	.48333	1.5374
			30	62	.48387	1.5386
	t 1	65	1	150	.00667	.1636
			0	131	.00000	.0000
		SZA	0	99	.00000	.0000
			0	143	.00000	.0000
		40	51	139	.36691	1.3016
			58	144	.40278	1.3772
		30	64	162	.39506	1.3596
			82	183	.44809	1.4670

TABLE 14 (continued)

SUMMARY OF DATA: SPEED VIOLATIONS

Location Station	Factor	Sign Cond.	m	n	z	u
D	t 2	65	0	129	.00000	.0000
		SZA	0	157	.00000	.0000
		40	16	147	.10884	.6724
		30	40	192	.20833	.9480
E	v 1	SZA	0 0	59 64	.00000 .00000	.0000 .0000
		40	11 18	56 90	.19643 .20000	.9182 .9272
		30	2 8	72 75	.02778 .10667	.3348 .6634
	v 2	SZA	1 0	57 81	.01754 .00000	.2658 .0000
		40	18 13	73 71	.24658 .18310	1.0394 .8844
		30	1 4	59 72	.01695 .05556	.2646 .4760
	t 1	SZA	1 0	116 145	.00862 .00000	.1860 .0000
		40	29 31	129 161	.22481 .19255	.9880 .9086
		30	3 12	131 147	.02290 .08163	.3038 .5796

TABLE 14 (continued)

SUMMARY OF DATA: SPEED VIOLATIONS

Location Station	Factor	Sign Cond.	m	n	z	u
E	t 2	SZA	0	119	.00000	.0000
		40	23	149	.15436	.8078
		30	16	161	.09938	.6416

APPENDIX C

ILLUSTRATIVE EXAMPLE

In order to understand more easily the special method used in the statistical analysis, an illustrative example with actual speed data is carried through. It is regarded superfluous to deal with the treatment of the frequency distributions to obtain the speed parameters desired. Any good textbook in applied statistics accomplishes that purpose, for example Burr (79) or Duncan (81). Powers (84) gives also a good description on analysis of frequency distributions related specifically to speed data.

Calculation of Error Mean Square

The illustrative example chosen deals with the significance test of the 85th percentile speed at station A 4. Table 15 shows the 85th percentile speeds recorded for various sign conditions by vehicle factor. This is a case with three replications in one cell and one in the others. The test method utilized requires one measurement per cell; consequently, the three measurements have to be converted into one by obtaining a weighted average. The procedure is outlined in Table 16. By definition the weighted mean is

$$\bar{X} = \frac{\sum_{i=1}^{n} n_i X_i}{\sum_{i=1}^{n} n_i}$$

TABLE 15

85TH PERCENTILE SPEED AT STATION A 4

	c 1	c 2	c 3	c 7
v 1	39.42	40.77	41.80 41.32 40.68	41.58
v 2	43.01	43.67	42.90 43.98 41.43	42.99

TABLE 16

CALCULATION OF WEIGHTED MEAN AND SUM OF SQUARES FOR REPLICATED DATA

v 1			
n_i	X_i	n_iX_i	$n_iX_i^2$
79	41.80	3,302.20	138,031.9600
92	41.32	3,801.44	157,075.5008
110	40.68	4,474.80	182,034.8640
281		11,578.44	477,142.3248

TABLE 16 (continued)

CALCULATION OF WEIGHTED MEAN AND SUM OF SQUARES FOR REPLICATED DATA

v 2			
n_i	X_i	$n_i X_i$	$n_i X_i^2$
85	42.90	3,646.50	156,434.8500
110	43.98	4,837.80	212,766.4440
103	41.43	4,267.29	176,793.8247
298		12,751.59	545,995.1187

For v 1: $\bar{X} = \frac{11,578.44}{281} = 41.2044$

For v 2: $\bar{X} = \frac{12,751.59}{298} = 42.7905$

From the same table the within cell sum of squares, SSg, is obtained, defined by (see also page 53)

$$SSg = \sum n_i X_i^2 - \bar{X} \sum n_i X_i$$

For v 1: $SSg = 477,142.3248 - (41.2044)(11,578.44) = 59.6517$

For v 2: $SSg = 545,995.1187 - (42.7905)(12,751.59) = 348.2068$

The total sum of squares within all the cells, SSk, is defined by

$$SSk = \sum SSg$$

Thus $SSk = 59.6517 + 348.2068 = 407.8585$

Dividing SSk with the sum of the degrees of freedom for each cell, respectively, an estimate is obtained of the mean square, MSk, based on

individual measurements

$$MSk = \frac{SSk}{\sum (g - 1)}$$

In this example $MSk = \frac{407.8585}{2 + 2} = 101.9646$

The error mean square, MSe, which, in fact, is a correction of MSk because of the reduction of replications within the cells is defined by

$$MSe = \frac{MSk}{\bar{n}}$$

where $\bar{n}$ is the harmonic mean of all the n_i's within the k cells:

$$\bar{n} = \frac{1}{\frac{1}{k} \sum_{k} \left[\frac{1}{\sum_{i=1}^{g} n_i} \right]}$$

The procedure of obtaining the harmonic mean is outlined in Table 17.

TABLE 17

CALCULATION OF HARMONIC MEAN

Sign Condition	v 1		v 2	
	n	1/n	n	1/n
c 1	116	.008621	90	.011111
c 2	107	.009346	76	.013158
c 3	281	.003559	298	.003356
c 7	109	.009174	117	.008547

$$\Sigma(1/n) = .066872$$

$$\bar{n} = \frac{1}{1/8 \cdot (.066872)} = 119.6315$$

Using that value of $\bar{n}$

$$MSe = \frac{101.9646}{119.6315} = .8523$$

However, this value is correct only if the variable X_i from Table 16 represents the mean speed. For speed percentiles a correction factor has to be applied, the value of which is given in Table 10. For the 85th percentile speed this factor is 2.3501. Accordingly, the error mean square for the 85th percentile speed is

$$MSe = \frac{0.8523}{2.3501} = .3627$$

This method, generally termed "unweighted mean's method," is thoroughly outlined by Snedecor (86).

Analysis of Variance

The second part of the analysis procedure is the analysis of variance, in this case, a two-way factorial design with one replication per cell. Table 18 delineates the general procedure of obtaining the various sum of squares.

The hypothesis we wish to test is that there is no difference between the speeds neither by condition nor by vehicle factor. Consequently, the alternative hypothesis is that there is a difference between the speeds. This significance test is delineated in a so-called

TABLE 18

CALCULATION OF SUM OF SQUARES IN ANOVA

	c 1	c 2	c 3	c 7	Σ
v 1	39.42	40.77	41.20	41.58	162.97
v 2	43.01	43.67	42.79	42.99	172.46
Σ	82.43	84.44	83.99	84.57	335.43

$$(T)^2 = (335.43)^2 = 112,513.2849$$

$$(Tc)^2 = (82.43)^2 + \ldots + (84.57)^2 = 28,131.2235$$

$$(Tv)^2 = (162.97)^2 + (172.46)^2 = 56,301.6725$$

$$(Tcv)^2 = (39.42)^2 + \ldots + (42.99)^2 = 14,078.5189$$

$$SSc = \frac{(Tc)^2}{2} - \frac{(T)^2}{8} = 14,065.6117 - 14,064.1606 = 1.4511$$

$$SSv = \frac{(Tv)^2}{4} - \frac{(T)^2}{8} = 14,075.4181 - 14,064.1606 = 11.2575$$

$$SScv = (Tcv)^2 - \frac{(T)^2}{8} - SSc - SSv =$$

$$= 14,078.5189 - 14,064.1606 - 1.4511 - 11.2575 = 1.6497$$

ANOVA table, Table 19. The result of the test is readily distinguished; the hypothesis that there is no significant difference between local and non-local vehicle speeds is rejected on a five per cent significance level due to the fact that the calculated F-value is greater, and in

TABLE 19

SIGNIFICANCE TEST

Source of Variation	df	Sum of Squares	Mean Square	F	$F_{.05}$
Condition c	3	1.4511	0.4837	1.3336	6.5914
Vehicle v	1	11.2575	11.2575	31.0380	7.7086
Interaction cxv	3	1.6497	0.5499	1.5161	6.5914
Error	4		0.3627		

this case even substantially greater, than the theoretical F-value. On the other hand, the hypothesis is accepted as to sign conditions and interaction.